VOLUME XXII NUMBER 9 WHOLE NUMBER 178

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

J. S. PLASKETT
Director of the Dominion Astrophysical Observatory, Victoria, B.C.

SIR FREDERIC STUPART
Director of the Meteorological Service of Canada, Toronto

R. MELDRUM STEWART
Director of the Dominion Observatory, Ottawa

PUBLISHED MONTHLY
(*Ten numbers per year*)

November, 1928

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

FOREIGN AGENTS: WHELDON & WESLEY LTD.
2-4 ARTHUR STREET, NEW OXFORD STREET, LONDON, W.C.

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXII, No. 9 NOVEMBER, 1928 WHOLE No. 178

Articles PAGE

The Modern Photographic Telescope and the New Astronomical Photography. Part IV—Astronomical Photography with very High Magnifying Powers - - - - *G. W. Ritchey* 359

Two European Astronomical Meetings - - - *C. A. Chant* 383

Review of Publication

Atlas de l'Hémisphère céleste boréal (Schüller) - *C. A. C.* 393

News and Comments

News of Astronomical Work, Chiefly Canadian - *REDeL* 394

Notes and Queries

Observation of the Aurora—Audibility of the Aurora—Astronomy in Literature—A Waning Moon on its Back in the West at Daybreak - - - - - - - *C. A. C.* 396

Upon request, made previous to publication of article, contributors will be supplied free either with fifty copies of the issue containing the article, or with the sheets containing the article stitched in a printed cover. If separate reprints are desired the cost will be as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$6 50	$ 9 50	$10 00	$13 00	$16 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

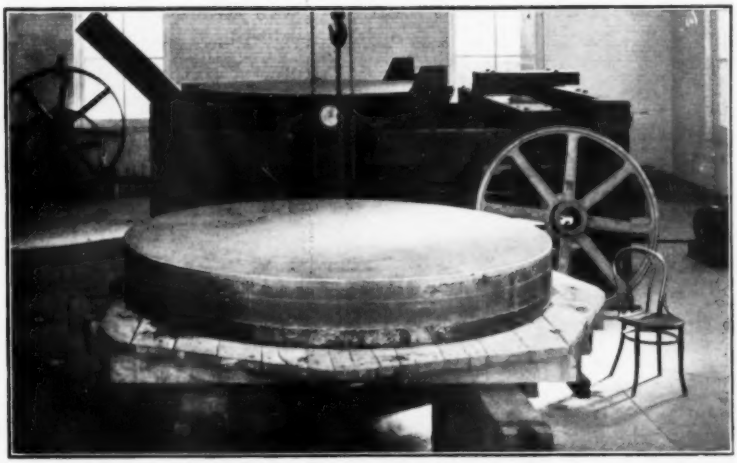
Business correspondence, remittances, etc., should be addressed to H. W. Barker, Treasurer of the Society, 198 College Street, Toronto.

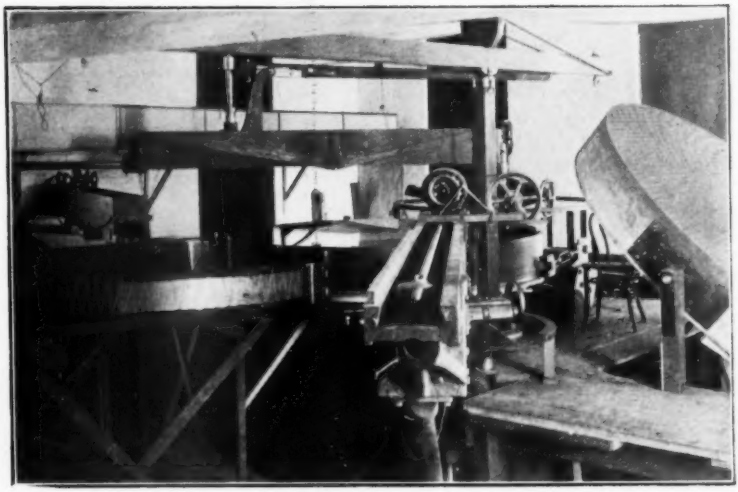
Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

PLATE X



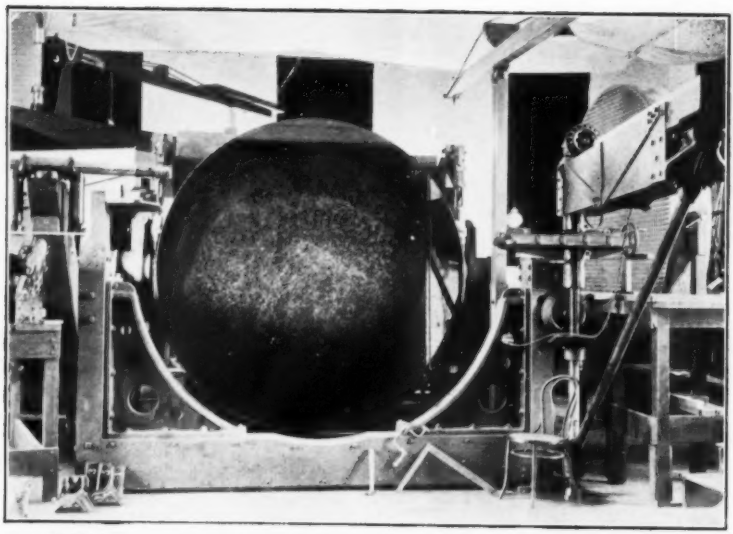


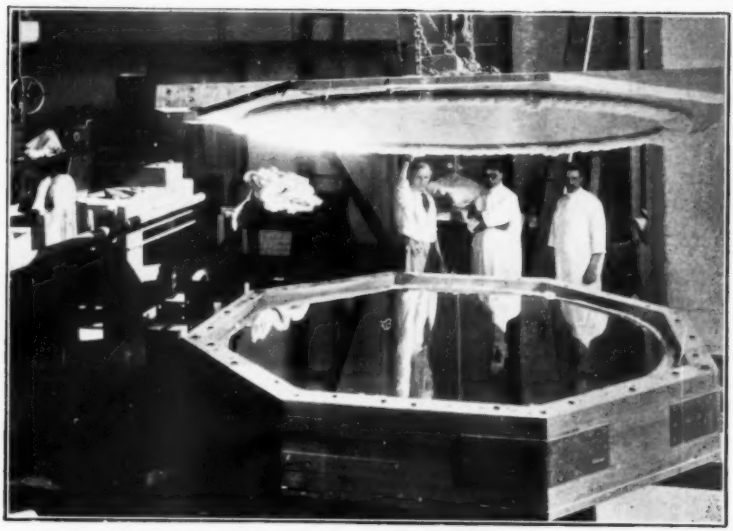
(a) *above.* The Rough Glass Disc for the 100-inch Hooker Telescope as it appeared on reaching Pasadena in December, 1908.

(b) *below.* The 100-inch Mirror lying horizontally on the Turntable of the polishing machine.

Journal of the Royal Astronomical Society of Canada, 1928

PLATE XI

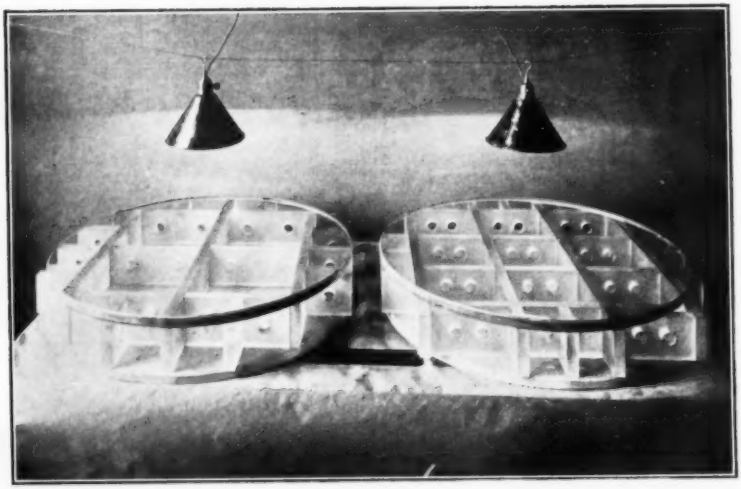


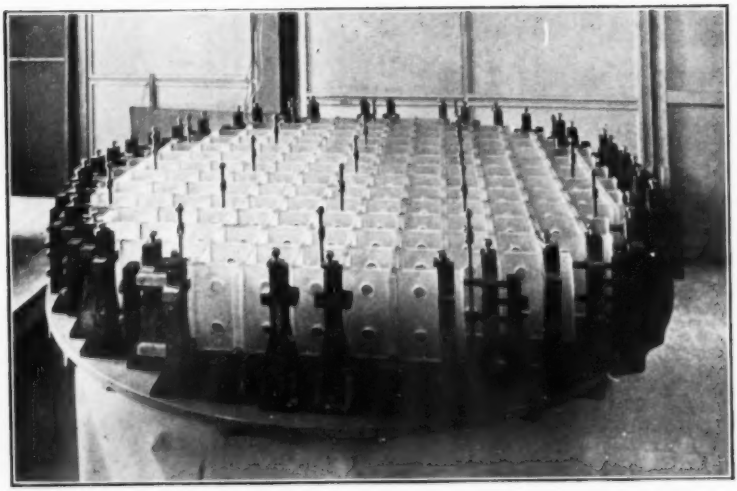


(a) *above.* The Polished 100-inch Mirror on edge, in the postion for testing.
(b) *below.* The 100-inch Mirror finished and silvered, in its cushioned octagonal box.

Journal of the Royal Astronomical Society of Canada, 1928

PLATE XII

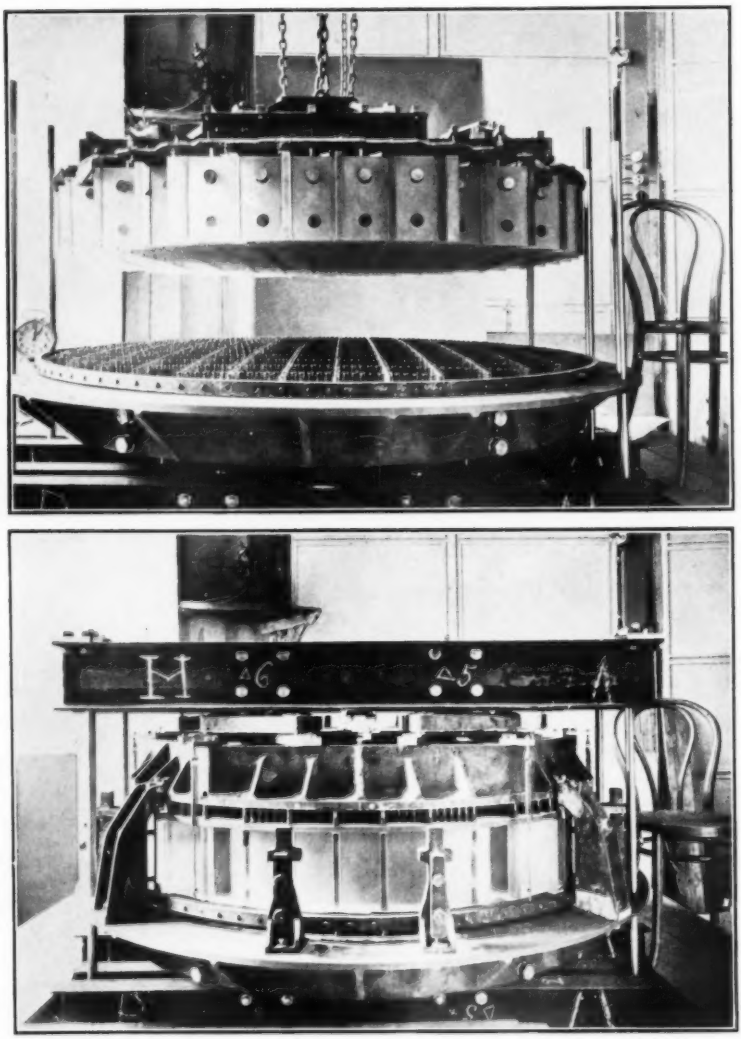




(a) *above.* Two 30-inch cellular Mirrors showing plan of construction.
(b) *below.* The interior Rib-system of a 60-inch Mirror.

Journal of the Royal Astronomical Society of Canada, 1928

PLATE XIII



(a) *above.* The Rib-system of the 60-inch Mirror after its front and back surfaces were ground to shape.

(b) *below.* The 60-inch Mirror in the Press used for cementing the front and back plates to the Rib-system.

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XXII, No. 9 NOVEMBER, 1928 Whole No. 178

THE MODERN PHOTOGRAPHIC TELESCOPE AND THE NEW ASTRONOMICAL PHOTOGRAPHY

By G. W. RITCHEY

PART IV—ASTRONOMICAL PHOTOGRAPHY WITH VERY HIGH MAGNIFYING POWERS

In the summer of 1910 I described the following investigation to Dr. C. O. Lampland of Lowell Observatory and to Dr. S. W. Stratton, then Director of the United States Bureau of Standards. In the spring of 1911 I described it to Dr. Elihu Thomson. Due to the optical work on the 100-inch mirrors, and to the great war, this investigation was not fully completed until 1919-20.

On many nights of finest atmospheric definition I observed the details of very bright planetary nebulae, the planets and the moon with the 40-inch Yerkes refractor. A special eye-piece was used, which gave a magnifying power of 2,400 diameters, and which could be used *with* and *without* finely-ruled cross-lines in its focal plane. My purpose was to study visually the conditions of highly-magnified telescopic images of bright celestial objects when atmospheric conditions were finest, in order to be able to design and construct a mechanism with which to *photograph* the *smallest* details *visible* with this great telescope. I found that the best details for this visual study were extremely small lunar craters. I estimated the diameters of these by comparison with the known diameters of larger craters in the same fields, which I had already photographed with the same refractor with yellow-sensitive photographic plates

and yellow ray-filter, with comparatively crude methods.[1] I found that the smallest craters whose circular form could be detected visually with certainty were 0″.13 to 0″.14 in diameter. The smallest craters shown in my published Yerkes photographs are about 1″.10 in diameter; examples of the latter are those in and near the northern exterior slopes of Theophilus, and those in the crater-floors of Clavius and Longomontanus.

A proportion of about one to eight was thus found to exist in the diameters of the smallest details which could be detected visually with the 40-inch refractor and of those which could be photographed at the focal plane of the same instrument by the method of a very short exposure (of about half a second), made at a *selected* instant.[2] I was deeply interested in finding the causes of this great difference, because of their bearing upon the ultimate problem of increased accuracy of measurement of astronomical photographs.

The focal length of the 40-inch refractor, 62.5 feet, is such that original negatives taken at the focal plane of this instrument, when viewed at the distance of distinct vision (10 inches), represent a magnifying power of about 75 diameters. When these negatives are examined with a microscope magnifying about 32 diameters, the total magnification is therefore about 2,400 diameters, and is equal to that used in my visual study of planetary and lunar details. When my Yerkes lunar negatives are examined with a microscope magnifying 32 diameters it is easily seen that the granulation of the Cramer Isochromatic plates used is so fine in comparison with the smallest details photographed that only a small part of the difference of one to eight can be ascribed to the granulation of the photographic plates used.[3] It is possible that slight errors were made in the focal settings when the best photographs were taken, which would account for a small part of the difference.

When making the visual observations and also the photographs I estimated atmospheric definition to be at 9.5 on my usual scale of 10. Using the eye-piece first *without* the finely-ruled cross-lines

[1] *Astrophysical Journal*, Vol. 12, 1900, page 352.
[2] Ritchey, *Decennial Publications*, University of Chicago, Vol. 8, 1904, page 392.
[3] These plates were selected for the writer by Mr. Benecke, snperintendent of the Cramer Company, and were of exceptionally fine granulation and great sensitiveness.

the extremely small lunar details appeared almost perfectly quiet. If very small, irregular movements of the telescopic images were present, due to any cause whatever, the eye instinctively followed these movements, without the observer being aware of their presence. The ring carrying the ruled cross-lines was now quickly inserted, and it was now seen that the minute craters were moving irregularly in every direction (largely due to irregular atmospheric refraction), even at instants of finest definition. The distances or paths of these movements varied from one to four times the diameter of the smallest craters visible; and the *frequency* of these movements was such that there was no possibility whatever of securing a photograph with the images at rest. The cross-lines were now removed, and again the small craters appeared quiet, the eye again unconsciously following the small irregular movements. It was clear that in order to *photograph* the smallest details which could be *seen* we must be able to correct for the small, irregular movements by means of an extremely light, small double-slide plate-carrier, and that the observer must be able to introduce the necessary corrections with very great speed and skill.

Another, and entirely different, effect of the sub-conscious action of the eye and mind in visual observations was distinctly observed, which has a most important bearing on our problem. I have spoken of "instants of finest definition". Even on the best nights ever seen at Yerkes Observatory the use of very high magnifying powers shows that atmospheric definition changes continually and intermittently. At the best instants the exquisitely small details come out sharp and distinct, often for a duration of two or three tenths of a second, sometimes for six or seven tenths of a second, seldom for a full second. The time *between* these best instants varies, in general, from one to four seconds. Perhaps the most remarkable effect noticed was that the mind of the observer, keenly intent on noting the exquisitely small details visible at the most favourable instants, disregard—*even forget*, the less favourable moments between. It was only by forcing the attention to observe *all* of these phenomena that it was realized that the instants of finest definition occupied only one-fifth to one-fourth of the total elapsed time. It was clear, therefore, that in addition to rapid and skilful guiding, the observer must learn to expose and to

cover the photographic plate with extreme quickness, so that the total exposure necessary would be built up, intermittently, only during the brief instants of finest definition, the photographic plate being covered at all other times. This would require an extremely sensitive, quick-acting shutter, which must be very light, and perfectly balanced in its action, so that it would not introduce perceptible shocks and vibrations.

The general plan of apparatus necessary to photograph the smallest details which could be seen was now evident. It was clear that in order that the observer should *have time* to introduce the necessary corrections of guiding and occulting, and for other reasons, it would be necessary to magnify the telescope image to such a degree, before photographing it, that the actual net exposure for planetary and lunar details would require with that particular telescope, about 85 seconds. This would permit a magnification of about 13 diameters of the original telescopic image before the light reached the photographic plate, even when moderately fine-grained photographic plates were used. The combination of enlarged image and fine-grained plates would reduce to one twenty-fifth or less the injurious effects of *granulation* which are encountered when photographing very small details of any kind with the most highly-sensitive commercial plates. The total elapsed time between beginning and end of exposure—the gross time—would be six or seven minutes (340 to 425 seconds), with the best moderately fine-grained commercial emulsions then available, such as *Seed 23*. This gross time of exposure would cause a slight loss of sharpness in photographing lunar details, because of the slowly-changing shadows. In photographing minute details of a rapidly-rotating planet, it is desirable to guide by means of the details as near as possible to the centre of the disk, and a slight loss of sharpness of all other details would result. A special device for guiding is, of course, necessary in this case. In photographing very small, brilliant planetary nebulae, an adjacent star would be used for guiding, and the gross time covered by the exposure could be prolonged as much as desired, without loss of sharpness. In photographing any of the classes of objects named, guiding would be done with the magnifying power of 2,400 diameters.

In the short and infrequent occasions of exquisite definition

suitable for such photography as that which we are considering, the observer cannot possibly gain the speed and skill in guiding and occulting which are necessary for the finest results. We might as well expect a musical *virtuoso* to gain his marvellous speed and skill by playing only at the times of his appearance before audiences.

For successful photography with very high magnifying powers, and for better results in *all* direct astronomical photography, the observer must use a double-slide *practice-machine* with which *systematically* to develop extreme speed and skill in guiding and occulting. This machine photographs artificial images which are as similar as possible to the real images of the celestial objects to be photographed. By means of suitable mechanism these artificial images are made to go through precisely the same kinds of small, irregular movements and precisely the same kinds of variations of sharpness as those of the real images seen in the guiding eye-piece of the telescope. The guiding and occulting mechanism used with the practice-machine must be precisely like that used for high-power photography with the telescope. Actual photographs of the artificial images must be made frequently with the practice-machine in order to test the improvement in speed and skill of the observer. The small irregular movements and the blurring of the artificial images must be made highly complicated, and must be capable of frequent alteration and reversal, so that the observer cannot possibly anticipate their sequence. These movements and blurring must be controlled by a variable-speed device, so that the observer can begin his practice with very slow movements and slow changes of sharpness, and can gradually increase the speed and frequency of these as he becomes more and more skilful. A recording and adding device must be provided, which records the duration of each short exposure, adds these together, and notifies the observer when the total net exposure desired has been made. This device is very simple in principle, but must be highly sensitive, because most of the short exposures to be recorded are of less than one-half second duration.

The double-slide plate-carrier used with the first practice-machine was similar to, but smaller and much lighter than, those which I designed and used with the 40-inch refractor, and with my 24-inch and 60-inch reflectors, but with the addition of a quick-

acting occulting-shutter. The two slides of the plate-carrier, at right angles to each other, were operated by two screws, the large milled heads of which are held in the observer's fingers. In all cases except that of planetary photography a guide-star or a very sharp lunar detail just outside of the field being photographed was watched constantly by means of a high-power guiding-microscope, rigidly attached to the light frame carrying the photographic plate. In the focal plane of the microscope were two diametral cross-lines of spider-web, one in the direction of motion in right-ascension, the other at right angles to this. Both lines were illuminated by faint red light. The image of the guide-object (star or other) was brought to the intersection of the cross-lines, and as this image was seen to move slightly and irregularly in all directions (this motion being due, in the telescope, to atmospheric conditions, and in the practice-machine to the mechanism of the machine itself), the observer endeavoured to keep the guide-star constantly at the intersection of the cross-lines by means of the guiding screws and slides. Since both hands were thus occupied the occulting shutter was operated by the observer's foot, through the use of a simple pneumatic device.

In order that the continuity of the above description should not be broken, I have not mentioned one important fact which, among others, made it impossible to test the new method on the sky at Yerkes Observatory. In the splendid Warner and Swasey mounting of the 40-inch refractor the anti-friction devices of the polar axis are hardened steel rollers and balls. The pressure required at the eye-end of the tube to move the telescope in right ascension is about 40 pounds; but at the periphery of the large worm-gear, about seven feet in diameter, which rotates the telescope in right-ascension, this pressure is greater than 300 pounds. In addition the gear-connections between the conical-pendulum of the driving clock and the tangent-screw which rotates the large worm-gear are all either spur-gears or bevel-gears. The result of these two conditions is that the slow rotation of this magnificent telescope in right-ascension (like that of *every other great* telescope in which the anti-friction devices, or the gear-connections, or both of these, are of the kind here described), when examined with a highly-sensitive test such as that used in the investigation which we are

considering, is seen to consist of a series of *short starts and stops*, very small in amplitude, but so rapid as absolutely to prohibit highly-accurate guiding in right ascension. This condition could have been partially relieved by weighting the moving parts of the telescope on the west side, to relieve the great pressure on the driving mechanism; but this was too dangerous for trial with that great telescope with any economical means, and was not attempted.

In observing and estimating the irregular movements of the small lunar craters described above, it was necessary to study only those movements which *could not* be due to instrumental causes, namely, those in declination, in order to reach a conclusion in regard to tremors due to atmospheric conditions alone.

It was precisely for the reasons just described that in designing and constructing the 60-inch Mt. Wilson reflector I floated in mercury the polar axis and all that it carries, and made the connections from the conical-pendulum of the driving-clock to the polar axis entirely by means of tangent screws and worm-gears, each pair of which *could be, and were*, fine-ground and polished together with almost optical accuracy.[4]

Returning now to our main subject: I studied later, with the full aperture of the 60-inch Mt. Wilson reflector, the details of planetary nebulae, the planets and the moon on several nights of exquisite definition, with special eye-piece which gave a power of 3,600 diameters. I was amazed to see the astounding, indescribable wealth of details shown—details so small as to appear of an entirely different order from those at the limit of resolving power of the 40-inch Yerkes refractor. Lunar craters of 0″.08 diameter were now distinctly recognizable as such. Precisely similar conditions in regard to small, irregular movements and intermittent blurring were seen, to those observed with the 40-inch refractor, but with the marked difference that now the small irregular movements in right ascension were no longer in amplitude and no more frequent than those in declination.

Although I had had many years' practice with various double-slide plate-carriers (always without the use of a very quick-acting occulting device), my first attempts with the practice-machine, in using simultaneously the occulting shutter and the two guiding

[4] *Astrophysical Journal*, Vol. 29, 1909, page 203 and following.

screws, led to much confusion. It was necessary to use, at first, a very slow setting of the variable-speed device referred to above. The confusion just mentioned was relieved to a surprising degree by arranging a small incandescent lamp in such a way that a faint, orange-coloured glow was seen in the guiding eye-piece while the occulting shutter was open; for by this means I could always see the effect of occulting. The effect of guiding was, of course, always visible.

The use of the practice-machine in the laboratory permits the operations of guiding and occulting to be systematically studied in ways which are not possible at the telescope. The profoundly interesting possibilities of the systematic use of the marvellous *human* mechanism are strikingly illustrated. For example, it is found that to make a consistent gain in speed and skill, as tested by making actual photographs of the moving and blurring artificial images, the observer must practice at least one hour every day. It is found that this amount of practice is much more effective when done in two half-hours, with a long interval between, than when done continuously. It is found that it is only by systematic practice every day that guiding and occulting simultaneously becomes gradually automatic or sub-conscious. It is found that when the latter characteristic is attained the work becomes remarkably smooth and easy; but that if systematic practice be suspended for one or two days a marked loss of this characteristic occurs, and the work becomes decidedly laborious.

In my first use of the practice-machine, but without attempting to use the occulting shutter, I was able to make, on an average, four or five corrections per second with the guiding slides—usually two with each hand. After six months of systematic practice with the first machine I was able to make at least eight corrections per second with the guiding slides—on an average four corrections with each hand; and during the same second often two complete exposures with the occulting shutter, that is, opening twice and closing twice.

In August, 1919, I was ready, and expected, to demonstrate the new method on the sky with the 60-inch Mt. Wilson reflector, which is the only *great* telescope the rotation of which is smooth enough to permit a *complete* demonstration to be made. But

insurmountable obstacles, other than technical and financial ones, prevented this demonstration. This method has never yet been demonstrated on the sky.

Despite this disappointment, and more serious ones which followed during the same year, a second practice-machine was designed and constructed in the autumn and winter of 1919. Experience with the first machine had shown that the speed and skill of the observer could certainly be developed to a degree far beyond the capacity of this type fully to utilize them. It was proved that the method of turning, with the fingers, the two fine screws which operate the two guiding slides is not the most favourable method for very great accuracy and speed. It was proved also that the method of operating the occulting shutter by the observer's foot could be greatly improved upon.

At this time the general plans for the fixed, vertical, universal telescope were far advanced. These required a *horizontal* guiding mechanism for the most promising of the component telescopes, the Schwarzschild, Ritchey-Chrétien and Cassegrainian, the fields of which are always horizontal, stationary and non-rotating in this fixed telescope. In addition, since the field of the Schwarzschild is inaccessible, the method of guiding *electrically*, with the observer at a considerable distance from the photographic plate-carrier, was thoroughly investigated.

The result of all these conditions was the development of the horizontal, electrically-operated practice-machine and guiding-mechanism. In these instruments the photographic plate and double-slide plate-carrier are always horizontal; the two former "slides" are replaced by two very light, rectangular frames moving on hardened steel balls, which, in turn, move in hardened-steel, straight V-grooves. The two fine screws which move the two frames, and the mechanism which opens and closes the occulting shutter, are operated electrically, in a manner similar to that used in modern pipe-organs for transmitting the action of the keys to the valves of the pipes. Two keys, pressed and released by the first and second fingers of the observer's right hand control the motions, to right and to left, of one of the guiding frames. Two similar keys operated by the left hand control the motions, toward and from the observer, of the other frame. A fifth key, operated

by the observer's lips, controls the opening and closing of the occulting shutter. After six months of daily practice in the laboratory with this machine I was able to guide and occult with approximately twice the speed which I had attained with the first practice-machine. This was fully demonstrated by very sharp photographs of the artificial images, made when the speed of their irregular movements and the frequency of their changes of sharpness had been increased to twice those which could be corrected for with the first machine.

The speed and skill thus attained are more than sufficient to correct for the conditions of atmospheric tremor and blurring seen on the finest nights with the 60-inch Mt. Wilson reflector with a power of 3,600 diameters. There can be *no question whatever* that the smallest lunar details thus seen can now be successfully photographed. And there can be no question that, with this same guiding and occulting, still smaller details than those detected visually will be photographed, and this approximately in proportion to the shorter wave-length of the blue-violet rays most efficient in photography. Still further, the choice of colour-sensitive photographic plates and ray-filters enables us to reveal extremely delicate contrasts of shading and of colour (of planetary details, for example), which are far beyond the power of the human eye to detect. All of these points, and many similar ones, I have fully demonstrated in the laboratory.

Few astronomers have ever seen such marvellous, minute details as those detected visually with the 60-inch reflector, on the finest nights ever seen at Mt. Wilson. Photographs showing these details, which are at least ten times smaller in diameter than any yet photographed, of planetary nebulae, planets, the moon and all similar, bright celestial objects, can now be made available for *all students*—not only for Astronomy, for Science, but for universal education.

This latest guiding-mechanism and practice-machine illustrates one phase of the almost limitless scope and possibilities of *direct* astronomical photography. These possibilities have been almost entirely unutilized up to the present time. Great photographic telescopes have been used, and continue to be used, with photographic plates, telescope mountings, photographic accessory in-

struments and methods of operation so crude and inefficient that *not one-tenth* of the real optical power of these telescopes is utilized.

It *ought* to be superfluous to state that *mere bigness* is no test of real worth and optical power of a telescope. This has been proved again and again in the history of Astronomy. The interested public should be well-informed of this fact. The public should know that a merely *big* telescope, one which is merely a big *light-collector*, but with which we can realize only a very small percentage of the magnifying power which is due to a given aperture, does not deserve the honourable name of a *telescope*. If such an instrument be named a *light-collector*, it is honestly named; it is but a feeble imitation of a telescope; for the sake of honour and truth in science it should be called by its right name.

As a definite example, let us imagine a 7-foot photographic reflecting telescope of a present-day type, and of 40 feet focal length, used at its Newtonian focus by the methods generally employed at present. Let us assume that photographs are being made at this focus for purposes of most precise measurement—for parallax and for proper-motion. Of course it is well known that photographs made at the Newtonian focus of such an instrument are not suitable for most accurate measurement, except for *very small fields*, because of the character of the out-of-axis images.[5]

Further, photographs as at present made at this focus and with this focal length, on commercial plates of very great sensitiveness, permit a maximum, total magnifying power of about 300 diameters to be used in measuring them, of which the factor *50 diameters* is due to the *scale* of the photograph, resulting from the focal length of the telescope, and the factor *six diameters* to the magnification given by the eye-piece of the measuring machine; this latter factor is limited by the degree of coarseness of granulation of the photographic plate used. If less sensitive finer-grained commercial photographic plates are used, such as *Seed 23*, a maximum, total magnifying power of 500 to 600 diameters can be used in measuring, because we can now use in the measuring machine an eye-piece magnifying 10 or 12 diameters. Frequently, however, photographs as at present made will not permit even *such* magnification, because of inaccurate guiding and focusing, of irregularities of the glass

[5]This JOURNAL, pages 224 and 225 of this series of papers.

surfaces of the commercial photographic plates used, which prevent very accurate focusing, of flexures and distortion of the optical mirrors, of very large flexures of the telescope tube, and so on.

But the *theoretical* photographic magnifying power for fields of stars, due to the 7-foot aperture, is not less than 10,000 diameters.[6] When atmospheric definition is very fine (which is *frequently* at the best observatory sites now found), the *new* methods of telescope construction and of celestial photography already developed in the laboratory, which include special photographic plates and emulsions, will now permit celestial photographs of such exquisite quality to be made that this *full theoretical* magnifying power for this aperture, 10,000 diameters, will be available in measuring them.

In that definite example of a Newtonian reflector which we have considered, and with the older methods of construction and of operation in general use at present, practically ninety-five per cent. of the real optical power due to the aperture is absolutely lost.

For the first time in the history of science super-telescopes of at least 17 feet aperture and of practically one hundred per cent. efficiency are now possible. Let us emphasize that the term "Super-telescopes" *here* refers to *quality* as well as to size. And let us emphasize that the term "one hundred per cent. efficiency" means precisely this: that this super-telescope will permit the *full, theoretical* photographic magnifying power due to this aperture to be *utilized*. This theoretical photographic magnifying power is 24,000 diameters for fields of stars, and is 14,500 diameters for celestial objects with extended surfaces, such as nebulae, planets and the moon. This telescope will show (by means of photographs) the general form of details on the moon which are as small as 100 feet in diameter; it will show the general form of details of the surface of Mars which are as small as 2.8 miles in diameter. It will photograph stars which are 1,600 times, or eight magnitudes, fainter than any yet photographed.

If the reader wishes to ask how these results will be achieved a general reply is as follows: Three of the principal means have already been briefly described in this series of papers: first, the fixed, universal telescope, which permits the almost complete elimination of those imperfections of photographic telescopes which

[6]Richey, *L'Astronomie*, May, 1928, page 228.

prohibit their most efficient use; second, the better star-images given by the new combinations of optical mirrors, the Schwarzschild and the Ritchey-Chrétien; and third, the use of the improved means of guiding: the practice-machine and the horizontal, electrically-operated guiding mechanism. These three improvements are absolutely indispensable. But no less important are (fourth) optical mirrors which rigorously retain their good optical figure (form) throughout the night. A fifth requirement, without which all of the others are greatly restricted in their use, is the *dual* one of fine atmospheric *definition* (tranquillity and homogeneity) and extreme atmospheric *transparency*. Of very great importance, also, are photographic plates with accurately ground and polished surfaces and with special photographic emulsions. Even with these refinements it is obvious—it is *axiomatic*—that such a telescope will be *cared for* and will be *operated* by highly-trained technicians.

A more specific reply to the above question is as follows: First, we must analyze and systematically study *all* of the conditions which affect the character of the *telescopic* images—the images which are given by the telescope, irrespective of the photographic plate. Second, we must analyze and systematically study *all* the conditions which affect the character of the *photographic* images—those on the finished negative. Third, through actual experience in celestial photography with great reflectors, through experiments in an astronomical laboratory, and through systematic search for the best observatory *sites*, we must find and apply the remedy for every injurious condition which detracts from the theoretical sharpness of these images. Fourth, we must secure the financial co-operation necessary to put the results thus found into effect: into actual telescopes and actual photographs of the heavens.

To conservative readers the statements made in the preceding paragraphs in regard to the possibilities of astronomical photography in the immediate future may appear exaggerated, or rash, or sensational. They *are* sensational, but they are neither rash nor exaggerated. In the two or three succeeding articles of this series I shall show precisely how these results can be, and will be, achieved.

One important point should be noticed: Critics will say that I am insisting that it is possible to have absolute perfection in the

conditions for this work. But instead, I insist only that it is possible to have the conditions necessary to take *complete* advantage of the *full, theoretical* magnifying power (resolving power) due to the aperture used. This "full, theoretical magnifying power" sets a definite limit to be attained; to confound this definite limit with absolute perfection is entirely misleading.

Large Optical Mirrors

Rigorous laboratory tests of silvered glass surfaces of which both the optical polish of the glass surfaces and the polish of the silver films are carried to the highest degree attainable, and in which the number and also the angles of the reflections used are the same as those of the four reflections in the Fixed Universal telescope, show that the *aggregate loss* of photographic light (wave-length $0^{\mu}.435$), due to the four reflections in this type of telescope is almost exactly 30 per cent. of the incident light.

My designs for these telescopes include special burnishing machines, motor-operated, with which the silver films are kept always at the highest degree of reflective power, by highly-trained technicians. Since all mirrors are quickly interchangeable (except the two 20-foot plane mirrors, for which special provision is made), they can readily be brought, on their carriages and flotation-systems, to a position accessible to the burnishing machines. The mirrors are all of cellular construction; no parts of their mechanical flotation-systems are near their silvered faces; therefore the motions of the large, light, machine-moved burnishing tools are never obstructed by adjacent metal parts. A good silver film is so hard that it permits perfect reburnishing at least fifty times by those who know *how* and *when*. In high, dry climates the silver films deteriorate very slowly if properly cared for by real experts.

Optically-polished surfaces of cast metal alloys, such as speculum-metal and stellite, when examined with even low-power microscopes, are found to be of granular or crystalline structure; even castings of moderate size invariably have porous areas which are extremely troublesome in optical work. But optically-polished surfaces of vitreous materials, such as glass, pyrex and fused quartz, have a perfectly *liquid* quality; their structure is so fine that these

surfaces, when clean, cannot be *found* with even a high-power microscope. When silvered, by either the chemical or the cathode method, the silver film, deposited molecule by molecule on the polished, vitreous surface, is so fine in structure that it takes the liquid quality of the vitreous surface. In addition, the silver film is so thin—about 0.0001 mm—that it retains perfectly the optical figure of the vitreous surface. Its structure is so fine and dense that it is nearly opaque to the brightest light. These qualities, taken together, account for the very high reflective power of silvered vitreous surfaces when they are kept in fine condition as described above. They account also for the fact that optically good mirrors with these surfaces permit the use of the full theoretical magnifying powers due to their apertures. These surfaces can therefore be regarded as *real optical surfaces*—a term which cannot properly be applied to the finest polished surfaces of cast, forged or rolled metal alloys, because the optically fine, liquid quality of surface is entirely lacking in the latter.

Optical mirrors of silvered vitreous material not only can safely be reburnished at least fifty times, but when the silver film becomes too thin it can be removed by nitric acid, and the mirror resilvered. With care there is not the slightest danger of injuring the polish or the figure of the vitreous surface while resilvering. But mirrors made of metal alloys must, in general, be refigured when they are repolished—an almost prohibitive labour and expense in the case of great mirrors.

Very large, solid disks of ordinary glass, of the thickness formerly considered necessary, and even when the best known composition to permit long annealing is used, invariably suffer *devitrification* to a very great extent during the weeks or months which are required for slow cooling called annealing. The most experienced glass-makers call such glass "rotten glass". Even when it is not *granular* to such a degree as to appear gray or opaque, experience has shown that a very large glass disk 13 inches thick has lost, through long annealing, a very great part of its supposed rigidity due to great thickness; it is at a stage far advanced toward devitrification—toward turning back to sand; it is certain that a very large disk *8 inches* thick would be *far more rigid*, because of the much shorter time required for annealing. The rigidity of disks of even the latter

thickness is very far below that indicated by present theories. These facts emphasize the importance of hollow or *cellular* mirrors *built up* of comparatively thin plates, since the glass of these plates is enormously strong and rigid in comparison with that of thick, *solid* disks.

Optical mirrors made of solid glass disks are subject, when the telescope is in use, to an "edge-effect" due to temperature changes; the outer parts of the mirror are exposed at front, back and edge; the inner parts at only front and back; therefore the edge zones are usually seen, optically, to be slightly high or low with reference to the inner zones. In the Mt. Wilson 60-inch mirror this effect extends in from the edge about five inches; in the 100-inch mirror at least 15 inches.

Cellular mirrors having positive (forced) ventilation throughout their interiors, when exposed to such temperature changes as ordinarily occur in the open dome at night, do not suffer changes of curvature sufficiently large to be detected by the most sensitive optical tests. *Plane* mirrors of this construction *remain optically plane* when in use on the sky, thus making possible, for the first time, great coelostats and great *fixed* telescopes of the highest optical quality. In addition, the built up, cellular construction permits the use of many comparatively small, selected units of low-expansion glass, pyrex or fused quartz; instead of, as hitherto, one very large unit, which, as experience shows, is almost prohibitively difficult to secure.

Not only is the internal rib-system of cellular mirrors constructed of comparatively small plates, but also, in great sizes, the circular front and back plates are constructed of six sixty-degree sectors, joined at their edges to make a single plate optically; these are fitted and joined by the same methods used for joining the parts of the internal rib-system, and for uniting the front and back circular plates to it. All plates used in a given mirror are selected for uniformity of thickness, of coefficient of expansion, of flexure-index, and for entire freedom from striae and bubbles. Better and better methods have been developed, nearly continuously for seventeen years, for *fitting* the adjacent vitreous surfaces to be cemented together; the fitting of these surfaces is now done by wholesale methods as accurate as those of the finest optical

work. Better and better cements, and the methods of applying them, have been gradually developed; the layer of cement remaining between the vitreous surfaces after cementing is finished is now only a small fraction of a *micron* in thickness. The cemented joints, as now made, are invariably stronger, under breaking tests, than the vitreous material itself. It now seems certain that we shall soon be able to unite all of the members without any cement whatever, and this as strongly and perfectly as if the entire cellular structure were a single piece of vitreous material.

At present cellular glass mirrors weigh one-fourth as much as solid glass ones of equal aperture. We expect to go much farther in the direction of lighter mirrors, and also in the direction of lower coefficient of expansion of the vitreous material used, until we come, in a few years, I believe, to cellular mirrors made of large, thin, selected plates of fused quartz. These developments will inevitably result in larger and larger apertures. Surely the day of metallic mirror disks, solid or other, for great apertures, is past; to return to them would be to go backward a century. And as surely the day of large, *solid* vitreous mirrors must soon pass. We shall look back and see how strange it was to insist upon using a thick, solid disk of vitreous material weighing several tons (almost prohibitively difficult to secure, and even then weak and non-rigid from long annealing, and having thousands of striae, and waves of millions of bubbles) in order to support in optical form a silver film weighing only a very small fraction of an ounce.

Cellular mirrors are not only enormously more rigid than solid ones, but they can be supported without sensible flexures in all positions, including face-down, with highly-effective *mechanical flotation*.[7] Due to the cellular construction, the *lateral* support given by this flotation can now be applied at the centre of gravity of each of as many interior and exterior segments of the mirror as desired, instead of *around the edge* as formerly. Cellular mirrors of any size whatever can be mechanically floated (supported), face-up or face-down, at any angle of inclination, as perfectly—as free from flexures as if floating horizontally in mercury.

The separate, comparatively small pieces of vitreous material for great cellular mirrors will be cast, *selected* and prepared, includ-

[7] Richey, *Smithsonian Contributions to Knowledge*, Vol. 34, 1904.

ing the preliminary fitting of the various pieces together, at the glass-factory or laboratory situated at a commercial centre. They will be *transported* in comparatively small, light pieces to the observatory site, and there joined together, and the mirrors figured optically.

M. Delloye, Director-General of the St. Gobain Glass Company, executive head of fifty-one great glass-factories, and one of the greatest masters, of all time, of glass-making in all of its forms, and of mechanical and optical engineering, has collaborated with me and my son for many years in this development. He agrees with us that cellular mirrors of practically perfect optical quality, up to ten meters (32.8 feet) diameter, constructed of plates of low-expansion glass, together with the latest types of mountings, domes and accessories for them, can now be constructed with the aid of the facilities now available, and with the laboratory experience gained since 1910, with much less uncertainty than that which attended the making of the largest reflectors now in use.

In the swiftly-coming day of ten-meter telescopes having light, cellular, fused-quartz mirrors, their optical figure unaffected by temperature changes, and mechanically floated without sensible flexures, face-up, face-down, or at any inclination which can occur in use; the telescope mirrors and mountings always used in fixed position, so that here, also, injurious temperature-effects and flexure-effects can be reduced practically to zero; with every refinement of astronomical photography suggested in this series of articles developed to a high degree of perfection; with astrophysical accessory-instruments used with all of the elaboration, stability and convenience possible in the best physical laboratories—we shall look back and see how inefficient, how *primitive* it was to work with thick, solid mirrors, obsolete mirror-curves, equatorial telescope-mountings of antiquated types requiring enormous domes and buildings, and similar anomalies in a progressive age.

In the swiftly-coming day when men and women—millions of us, of every nationality and of every station in life—shall refuse longer to be satisfied with "small-town" ideas, when we shall cease to permit our view, our thought, our interest, our imagination, to be limited to one small world—to one microscopic corner of the *universe* of worlds; when we shall come to take precisely the

same kind of interest in the other *planets* of our sun's marvellous *family* of planets—in Mars, for example—as we now take in foreign countries and peoples, we may be *certain* that that interest will soon be *realized*. We may be sure that when the idea, the conception, of a *stellar system*, a Milky Way, a Galaxy, consisting of *tens* of *billions* of *suns*, shall come to mean at least as much to us as majestic architecture or supreme art or glorious music mean; and when the revelation, by means of actual photographs, of a *universe* consisting of tens of millions of such Galaxies, of similar stellar systems, shall become to us like an infinite symphony of the Creator; *then* we shall have the *generous* means to construct those great and perfect telescopes which will distinctly reveal so many of the mysteries of that universe. As cathedrals and churches, as universities and schools, are dedicated to God and to the highest ideals of men, so these super-telescopes will be dedicated, and soon.

To pharaphrase Victor Hugo: Is this a practical thought? Is this aspiration a realizable one? M. Delloye and the Saint-Gobain Company answer "yes". My astronomical laboratories, with forty years of continuous experimenting, answer "yes". The 60-inch reflector and the photographs made with it, preliminary though they be, answer "yes". It is not only a realizable aim, it is an *inevitable* one. We may oppose, or we may nobly hasten, its advent; we cannot halt its swift coming. He would have been denounced as a half-insane dreamer—the prophet, who, a half-century ago, would have predicted the incredible revelations now already made by means of photography with reflecting telescopes now in use. Astronomers all know this—not one can be found anywhere who will deny it. Yet it is certain that vastly *greater* revelations *still* can be made in the immediate future by means of the better telescopes and better photographic methods already invented and described. Again I point out that the real possibilities and technical refinements of celestial photography, although demonstrated, are as yet practically untouched, unutilized, in astronomy.

The 100-Inch Hooker Mirror of Mt. Wilson Observatory

In Plate X*a* we see the rough glass disk for the 100-inch Hooker reflecting telescope as it appeared when it reached Pasadena in

December, 1908. It was cast by the Saint-Gobain Company, by pouring into a red-hot iron mould the contents of three largest-size fire-clay pots of molten glass. The composition or mixture of ingredients used permits very long annealing without extreme *devitrification* (page 373). This disk was annealed for three months.

In its rough state the disk was 102 inches in diameter, 13 inches thick, and weighed nearly five tons; each pot-full of glass used in casting it weighed nearly one and three-fourths tons. The grinding of the cylindrical edge of the disk and of the front and back surfaces, including the large, concave surface, reduced the weight to about four and one-half tons.

In Plate X*b* we see the 100-inch Hooker mirror lying horizontally upon the turntable of its grinding and polishing machine. Its polished, concave, unsilvered surface, reflecting some of the details beyond it, is well seen. The depth of the curve of the concave surface is one and one-fourth inches. The full-size, convex polishing-plate, suspended on its trunnions, is seen at the extreme right; the chair near it gives the scale of things. The strong, cushioned, steel edge-band in which the mirror hangs when it is being turned down on edge for optical testing, is shown at the left-hand side of the glass. The larger of the two long, reinforced wooden "arms", which communicate the motions of the two large cranks to the grinding and polishing plates, is seen above the glass, and extending far to the left of it. The smaller of the two arms is seen, much distorted by perspective, in the near foreground.

In Plate XI*a* we see the polished mirror as it appeared when supported on edge in the position for optical testing. The chair and tools in the foreground assist in giving the scale of the picture. The two very large trunnions of the grinding and polishing machine are seen at the left and right of the glass; they permit the mirror, its turntable, its rotating-mechanism, and the massive frame which carries all of these, to be turned quickly from the horizontal to the vertical position without removing the glass from its cushioned table. The full-size polishing-plate is seen at the right, hanging vertically on its supports.

In the interior of the glass are seen great waves and striae, which consist of myriads of very small bubbles; these are due in part to the method of pouring the molten glass from three pots in

succession. The front, concave surface of the glass is almost perfectly free from even small bubbles.

The concave, *spherical* surface, to which the mirror was first polished and silvered, had a *radius of curvature* of about 84.5 feet. At this distance from this surface, that is, near the *centre of curvature*, a very small and brilliant *artificial star* was placed. Light from this star shone upon the polished, unsilvered, concave surface of the mirror, and was reflected to a focus close at one side of the artificial star. This reflected focus or image was examined with an eye-piece and also with the aid of a sharp *knife-edge*. By these means, with many elaborations and many precautions against temperature and atmospheric difficulties, the mirror was optically tested, visually, nearly every morning, in preparation for each day's figuring.

After the concave surface was fully polished and was figured to a practically perfect spherical surface it was changed gradually to a *paraboloid of revolution*. This was done almost entirely by means of light polishing-plates operated by the large machine. When the paraboloidal form was far advanced, optical testing was done visually each morning, not only at the centre of curvature, but also at the *focus* of the paraboloid. The test at the focus requires the use of a large, optically *plane* mirror in combination with the large paraboloidal one. A 60-inch plane mirror of the finest quality was specially prepared and figured for this test, and for the later, daily tests of the two secondary, convex, *hyperboloidal* mirrors which can be used in the telescope for securing two Cassegrainian combinations. All of these optical tests have been fully described by the writer in former publications.[8]

Plate XI*b* shows the finished and silvered 100-inch mirror lying horizontally in its cushioned, octagonal box, as it appeared when being packed for transportation up Mt. Wilson.

The clear aperture of the finished mirror is 101 inches. The area of the 101-inch figured surface is 8,012 square inches. The focal length is 507.5 inches, or 42.29 feet. The thickness of the finished glass at the edge is 12.75 inches. The depth of the concave surface is very nearly 1.25 inches. The depth of the finished paraboloid

[8] *Astrophysical Journal*, Volume 19, 1904, page 53; *Smithsonian Contributions to Knowledge*, Volume 34, 1904.

differs from that of the nearest spherical surface (to which the mirror was first figured) by almost exactly 0.001 inch at the centre, where the difference is greatest.

When the mirror is properly supported (mechanically floated) in the optical laboratory, and when, simultaneously, temperature conditions have been held constant for about 24 hours so that the figure of the mirror is normal, the largest *error* of the approximately paraboloidal surface is at a zone nearly midway between the centre and the edge, and amounts to 0.000003 *inch* of depth.

In order to comprehend better the amount of this error, let us imagine all of the proportions of the mirror—its diameter, radius of curvature, and so on, *enlarged* 250,000 times, so that its radius of curvature would now be about equal to the radius of the earth, or 4,000 miles. The curvature of the mirror would now be about the same as the curvature of the surfaces of the earth's oceans (but, of course, concave instead of convex). The diameter of the mirror would now be about 400 miles, the depth of its concave surface about five miles, the greatest difference between the paraboloid and the nearest spherical surface about 21 feet, and the largest *error* of the paraboloidal surface (as described in the preceding paragraph) about three-fourths of an inch.

The optical work of the 100-inch Hooker telescope included the making of two secondary, convex, hyperboloidal mirrors, which, with the great mirror, give two Cassegrainian combinations of this telescope. Special apparatus, both mechanical and optical, was made for the daily, optical testing of these secondary mirrors while they were being figured. These tests were necessarily made in combination with the finished and silvered 100-inch paraboloid and the 60-inch optical plane mirror.

The larger one of these convex mirrors is 28.75 inches in diameter, is 6.5 inches thick, has a radius of curvature of 346.7 inches, and gives, with the great mirror, an equivalent focal length of 1,607 inches, or 133.9 feet.

The smaller convex mirror is 25 inches in diameter, is 5.5 inches thick, has a radius of curvature of 274.9 inches, and gives, with the great mirror, an equivalent focal length of 3,011 inches, or 250.9 feet.

The optical work of the 100-inch Hooker reflector, as outlined

here, required the greater part of the time and intense care of the writer, with two assistants, for five years.

Experimental Work on Large Cellular Mirrors

In collaboration with M. Delloye and the Saint Gobain Company, and with the generous financial support of M. and Mme. Dina, a great amount of experimental work on large cellular disks for optical mirrors has been done by the writer in his laboratory at Paris Observatory. A general description and discussion of this construction of mirrors has been given in this article.

In Plate XII*a* we see the general plan of this construction. The two mirrors here shown are 30 inches in diameter. The plates of glass here used are one inch thick. The arrangement of the rib-systems, the holes for ventilation of the interior of the disks, and the closer spacing of the ribs around the edges, are shown. These plane mirrors were made in the course of experiments for determining the maximum separation of the ribs permissible with this thickness of glass plates.

Plate XII*b* is from a photograph of the interior rib-system of a 60-inch cellular mirror, which was purposely made of unusually *thin* glass plates, in order that it might serve as a *model*, constructed to scale, for cellular mirrors of ten feet or twelve feet diameter. The glass plates used are only 0.6 inch thick; the depth of the rib-system is 8 inches. This rib-system, after being cemented together in the press (a part of which is shown in this illustration), was so strong that it could be lifted, turned over, fine-ground for fitting the front and back plates to it, and so on, precisely as if it were a very light, solid, single disk of glass.

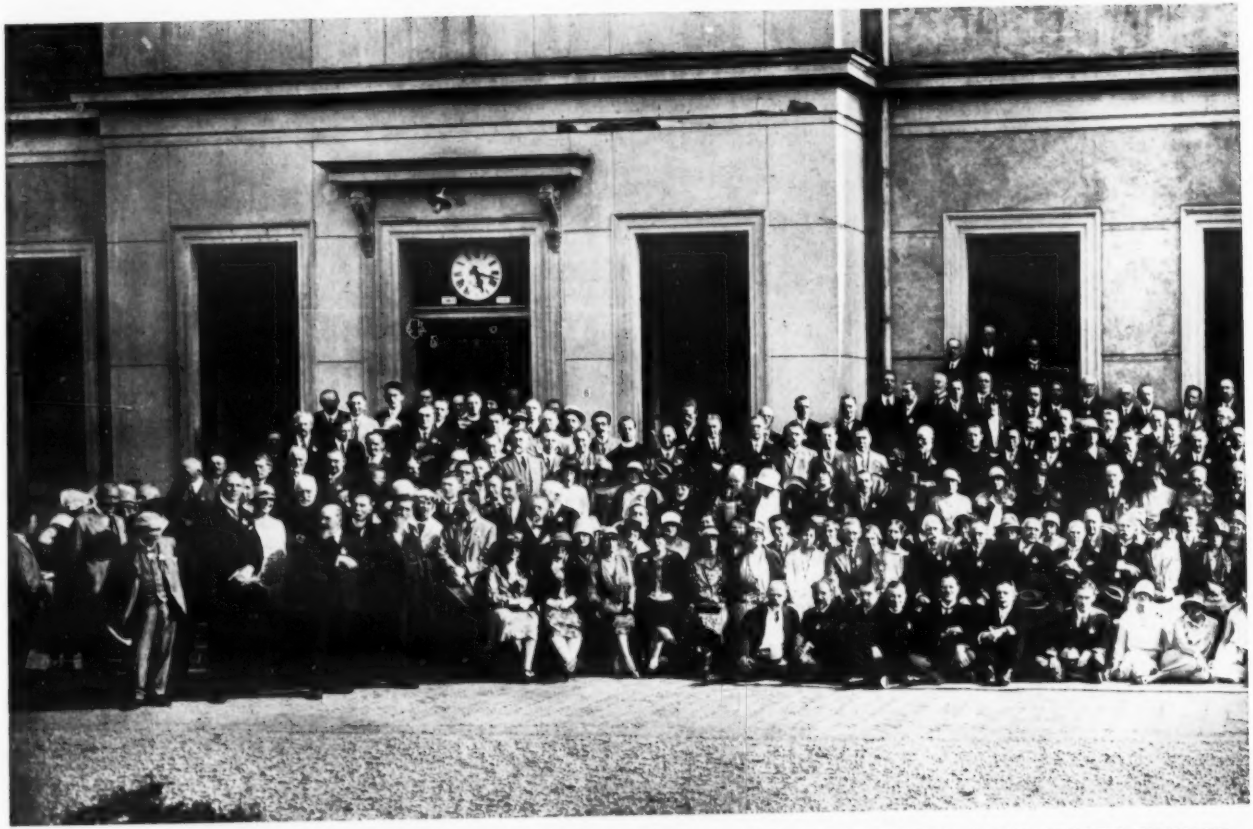
Plate XIII*a* shows the same rib-system after its front and back surfaces were fine-ground to fit the circular, curved, front plate and the circular flat, back plate of the mirror. The curvature of the lower surface of the suspended rib-system is easily seen. The system of spiral springs is seen below, which is used for applying the pressure during the cementing of the curved (lower) plate. A similar system of spiral springs is used, simultaneously, for cementing the flat upper plate.

The rib-system is shown suspended (supported) at 150 points on a mechanical flotation-system which was used while fine-grinding

the front and back faces of the rib-system. Since the weight of the rib-system is about 300 pounds, the weight on each of the points of support is about two pounds.

Plate XIII*b* shows the 60-inch cellular mirror in the press used for cementing, simultaneously, the circular, front and back, glass plates to the finished rib-system. The pressure is applied to both plates through the medium of rows of spiral springs, and is applied only in the lines of the ribs of the interior, glass rib-system. After the cement is applied, and after the pressure is given as here illustrated, the walls and ceiling of the drum-shaped *oven* (not shown) are lowered over the mirror. The temperature is now very slowly raised to 140° C., where it is automatically held constant for several weeks. The temperature is then very slowly lowered to normal. The concave surface of the front, concave glass plate is then fine-ground, polished and optically figured by the same methods used for a solid mirror.

Paris Observatory, September 18th, 1928.



DELEGATES AND VISITORS AT THE THIRD MEETING OF THE INTERNATIONAL ASTRONOMICAL UNION, LEYDEN, HOLLAND, July 5-13, 1928. (Part 1)

(Courtesy of *Popular Astronomy*)

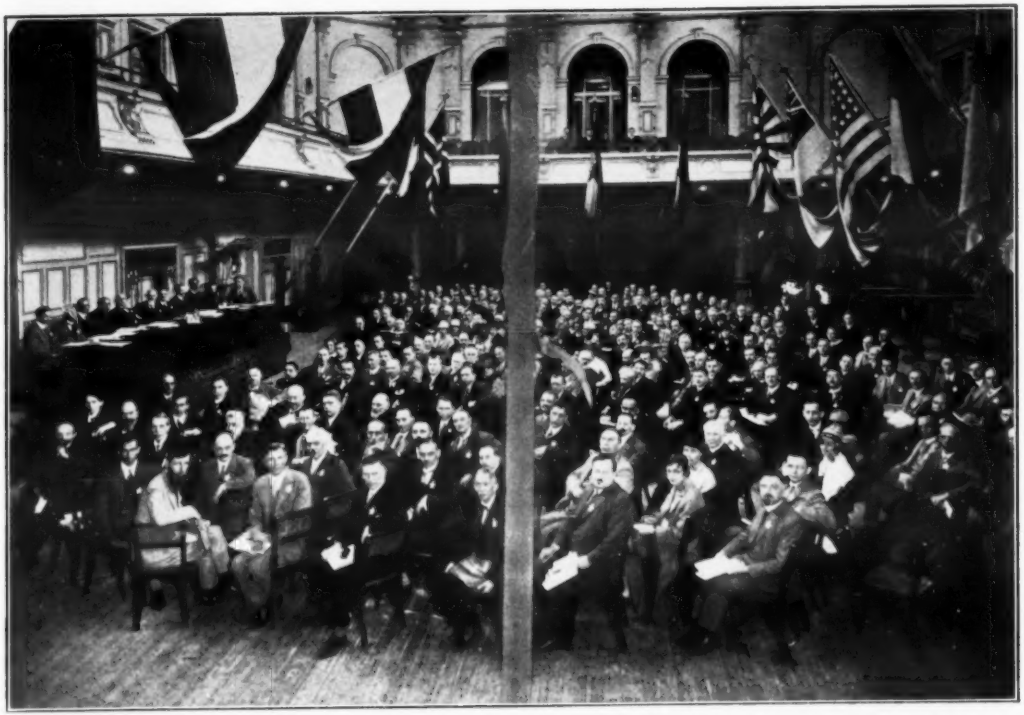
DELEGATES AND VISITORS AT THE [illegible]

July 5-13, 1928. (Part 1)

(Courtesy of *Popular Astronomy*)

DELEGATES AND VISITORS AT THE THIRD MEETING OF THE INTERNATIONAL ASTRONOMICAL UNION, LEYDEN, HOLLAND, July 5-13, 1928. (Part 2)

(Courtesy of *Popular Astronomy*)



THE FIRST SESSION OF THE GENERAL ASSEMBLY OF THE INTERNATIONAL ASTRONOMICAL UNION, IN THE CONCERT ROOM OF THE CITY AUDITORIUM, July 6, 1928.

Journal of the Royal Astronomical Society of Canada, 1928

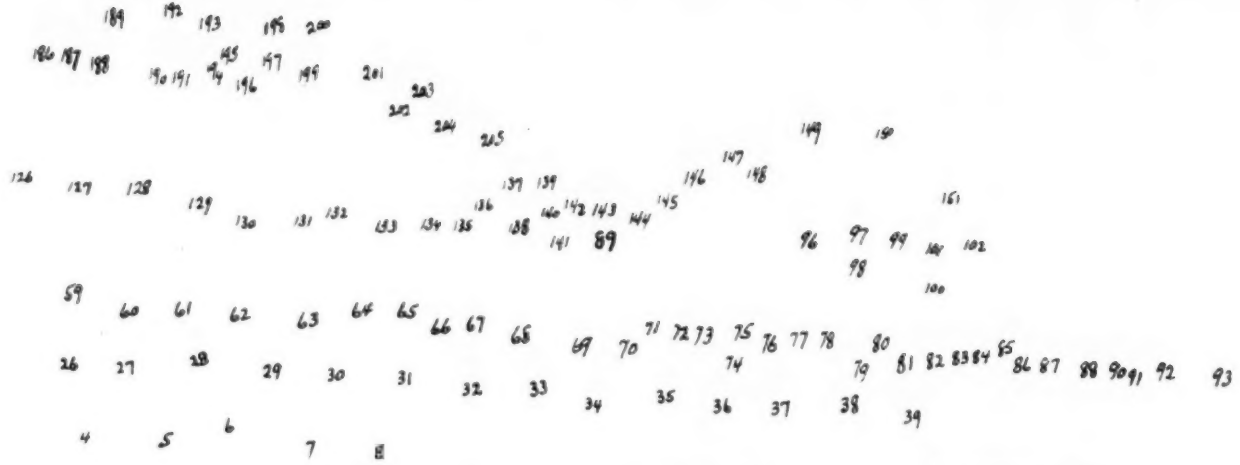
THE TWENTY-EIGHTH MEETING OF THE ASTRONOMISCHE GESELLESCHAFT, HEIDELBERG
July 18-21, 1928. (Part 1)

Journal of the Royal Astronomical Society of Canada, 1928 (Courtesy of *Popular Astronomy*)

KEY TO PLATE XVII

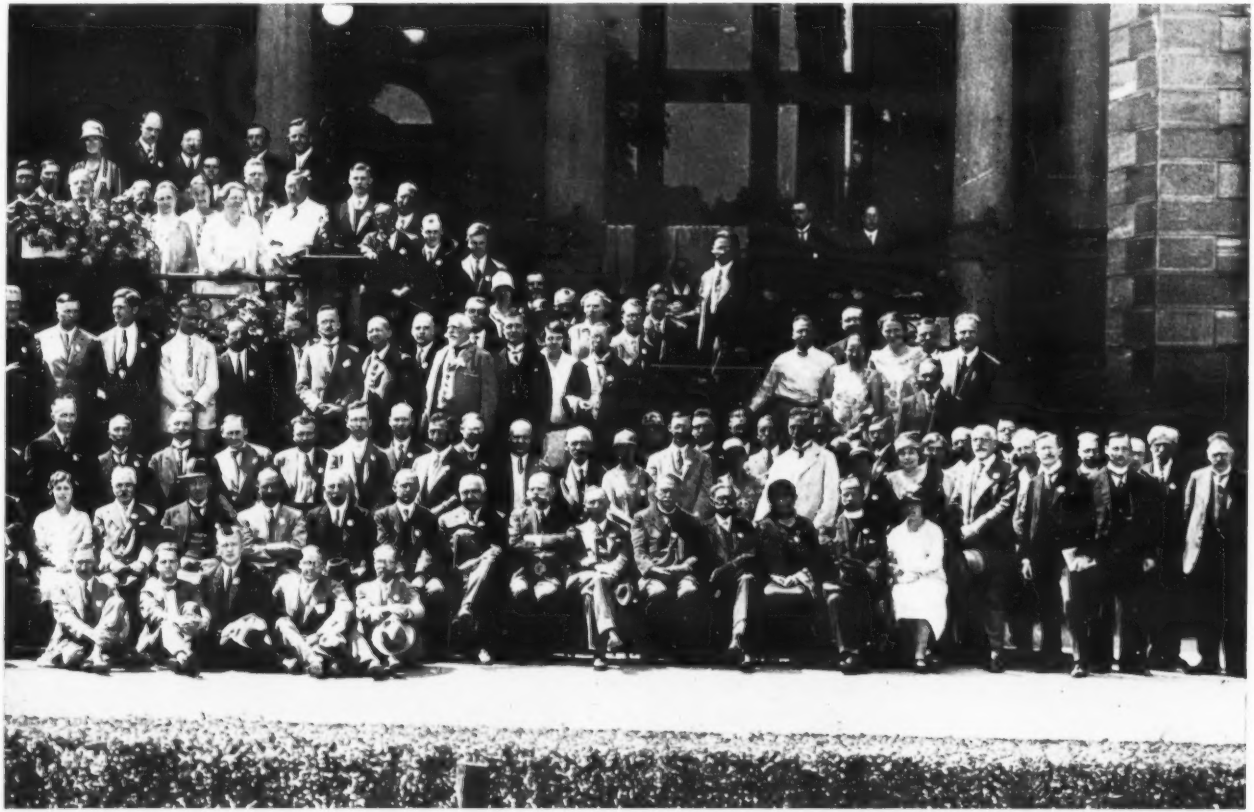
KEY TO PLATE XVII

1. Dugan, Princeton
2. Priscilla Dugan, Princeton
3. Mrs. Dugan, Princeton
9. Mrs. Prager, Babelsberg
10. Mrs. Prey, Prag
11. Mrs. Oppenheim, Vienna
12. Carrasco, Madrid
13. Mrs. Carrasco, Madrid
14. Mrs. Kohlschutter, Bonn
15. Schorr, Bergedorf
16. Herzog, Ernst von Sachsen, Wolfersdorf
17. Mrs. Stromgren, Copenhagen
18. Rosenberg, Kiel
19. von der Pahlen, Potsdam
20. Kudrjavtzew, Kharkow
21. Bauschinger, Leipzig
22. Wolf, Heidelberg
23. Kobold, Kiel
24. Lady Dyson, Greenwich
25. Stromgren, E., Copenhagen
40. Elmer, F. D., New York
41. Elmer, C. W., New York
42. Olivier, Philadelphia
43. Pickering, East Orange
44. Weber, Leipzig
45. Beer, Breslau
46. Becker, Potsdam
47. Komendantoff, Pulkovo
48. Vogt, Heidelberg
49. Mrs. Vogt, Heidelberg
50. Esch, Valkenburg
51. Nordlund, Hudiksvall
52. Miss Essenberg, Damascus
53. Miss Nusl, Prag
54. Svoboda, Prag
55. Stumpff, Breslau
56.
57. Anding, Gotha
58. Schlier, Heidelberg
94. Miss Harwood, Nantucket
95.
103. Schaub, Hann
104. Stabbe, Babelsberg
105. Jackson, Greenwich
106. Mrs. Merton, Greenwich
107. Mrs. Jackson, Greenwich
108. Plummer, Woolwich
109. Merton, Greenwich
110. Larink, Bergedorf
111. Boda, Frankfurt a. m.
112. Mrs. Boda, Frankfurt, a. m.
113. Morgan, Washington
114. Robbins, London
115. Meissner
116. Hulgeler, Berlin
117. Rosenthal, Heidelberg
118. Schonberg, Breslau
119. Dingle, Greenwich
120. Dneprowsky, Pulkovo
121. Stevenson, London
122. Luyten, Harvard
123. Campbell, Harvard
124. Slavenas, Kovno
125. Kepinski, Warschau
152. Mrs. Larink, Bergedorf
153. Kohlschutter, Bonn
154. Ivanoff, Pulkovo
155. Wirtz, Kiel
156. Michailoff, Moscow
157.
158. Zimmerman, Garlitz
159.
160. Plaskett, Victoria
161. Mrs. Plaskett, Victoria
162. Tass, Buda Pest
163. Gertrude Gingrich, Northfield
164. Eichelberger, Washington
165. Stracke, Berlin
166. Gingrich, Northfield
167. Kienle, Gottingen
168. Mrs. Gingrich, Northfield
169. Hellerich, Kiel
171. Stratton, Cambridge
172. Mrs. Mahnkopf, Potsdam
173. Mrs. Luther, Dusseldorf
174. Luther, Dusseldorf
175. Mitchell, Charlottesville
176. Mrs. Hellerich, Kiel
177. Innes, Johannesburg
178. Mrs. Konig, Bonn
179. Meyermann, Gottingen
180. Konig, Bonn
181. Schwassmann, Bergedorf
182. Rouse, Bergedorf
183. Schrader, Berlin
184. Mrs. Rouse, Bergedorf
185. Rosenlecker, Hochst, a.m.



4. Baade, Bergedorf
5. Jordan, Mannheim
6. Kordylewsky, Cracow
7. Lehmann, Bonn
8. Nusl, Prag
26. Mrs. Jones, Cape Town
27. Sir Frank Dyson, Greenwich
28. Ludendorff, Potsdam
29. Jones, Cape Town
30. Guthnick, Babelsberg
31. Eddington, Cambridge
32. Schlesinger, New Haven
33. Mascart, Lyon
34. Chant, Toronto
35. Knopf, Jena
36. Kucera, Zagreb
37. Mrs. Roberts, San Francisco
38. Rodes, Tortosa
39. Miss Eddington, Cambridge
59. Hoffmeister, Sonneberg
60. Kimura, Mizusawa
61. Wilkens, Munich
62. Hufnagel, Warschau
63. Schilt, New Haven
64. Lindblad, Stockholm
65. Petersen, Upsala
66. Bernheimer, Vienna
67. Nordennark, Stockholm
68. Lichtenstein, Leipzig
69. Oppenheim, Vienna
70. Miss Vinter Hansen, Copenhagen
71. Mrs. Kopff, Berlin
72. Slocum, Middletown
73. Kopff, Berlin
74. Mrs. Slocum, Middletown
75. Knox-Shaw, Oxford
76. von Kluber, Potsdam
77. Munch, Potsdam
78. Philipps, Washington
79. Mrs. Chant, Toronto
80. Sticker, Bonn
81. Mrs. Mitchell, Charlottesville
82. Miss Fairfield, Northampton
83. Rogers, Hartford
84. Carnera, Trieste
85. Bottlinger, Babelsberg
86. Miss Bigelow, Northampton
87. Mundler, Heidelberg
88.
89. Peters, Berlin
90. Lindow, Munster i. w.
91.
92. Jewdokimoff, Kharkow
93. Vick, Bergedorf
96. Wegner, Bonn
97. Prager, Babelsberg
98. Mrs. Kahrstedt, Berlin
99. Miss Allstadt, Heidelberg
100. Asplind, Karlstad
101. Kahrstedt, Berlin
102. Reinmuth, Heidelberg
126. Angehrn, Kalocsa
127. Thomas, Vienna
128. Dawson, LaPlata
129. Hartner, Frankfurt a. m.
130. Madwar, Helwan
131. Carroll, Cambridge
132. Ritter, Heidelberg
133. Villiger, Jena
134. Heinemann, Berlin
135. Green, Breslau
136. Gramatzki, Berlin
137. Miss Peters, Berlin
138. Courvoisier, Babelsberg
139. Meyer, Jena
140. Mrs. Tass, Buda-Pest
141. Mrs. Schaub, Hamm
142. Mahnkopf, Potsdam
143. Mrs. Peters, Berlin
144. Heckmann, Gottingen
145. Siedentopf, Gottingen
146.
147. Hopf, Berlin
148.
149. Kaiser, Wiesbaden
150. Gondolatsch, Berlin
151.
186. Bohrmann, Heidelberg
187. Zanstra, Seattle
188. Haussmann, Schw. Gmund
189. Miss Furness, Poughkeepsie
190. Prey, Prag
191. Mrs. Knopf, Jena
192. Macdonald, Glasgow
193. Lundmark, Upsala
194. Miss Gussow, Bergedorf
195.
196. Mrs. Hins, Leiden
197. Hins, Leiden
199. Hoffman, Bonn
198. Kuhl, Munich
200. Schutte, Munich
201. Wildt, Bonn
202. Bruner, Zurich
203. Oberguggenberger, Innsbruck
204. Ohman, Upsala
205. Stromgren, B., Copenhagen

65. Petersen, Upsala
91.
92. Jewdokimoff, Kharkow
143. Mrs. Peters, Berlin
144. Heckmann, Gottingen
205. Stromgren, B., Copenhagen



THE TWENTY-EIGHTH MEETING OF THE ASTRONOMISCHE GESELLESCHAFT, HEIDELBERG
July 18-21, 1928. (Part 2)

(Courtesy of *Popular Astronomy*)

THE VISIT OF THE MEMBERS OF THE ASTRONOMISCHE GESELLESCHAFT TO THE KEPLER MONUMENT AT WEIL DER STADT, GERMANY.

The three persons standing directly in front of the monument are (left to right) Stroemgren, Eddington, Wolf.

Journal of the Royal Astronomical Society of Canada, 1928

PLATE XX

Above. A Group at the Garden Party in the Botanic Garden, Leyden. Sir Frank Dyson (at left), Dr. W. J. S. Lockyer (in middle), Lady Lockyer (at right). The others are Leyden young ladies in peasant costume.

Below. A View from the top of the Library Building of the Koenigstuhl Observatory, Heidelberg.

Journal of the Royal Astronomical Society of Canada, 1928

TWO EUROPEAN ASTRONOMICAL MEETINGS

By C. A. Chant

I. The International Astronomical Union

In 1919, the year after the Armistice, a number of leaders in the world of science met in Brussels and instituted the International Research Council; and through it several "Unions" were organized, one of them being the International Astronomical Union. Its first meeting was at Rome in 1922, the second at Cambridge in 1925, and the third at Leyden, Holland, in July last.

When first organized membership in the Union was limited to nations which were neutral or on the side of the Allies during the war. Thus Germany was not eligible. As everyone knows, that nation is very active in scientific research, and any organization cannot be really international which excludes it. This sentiment was so strong that at the Cambridge meeting a resolution was passed requesting the International Research Council to admit any nation which was a member of the League of Nations, and the Council acted favourably to this request. It was felt also that the holding of the meeting in Holland, a neutral country and easily reached from all parts of Europe, would help to bring together the nations which had been separated by the war.

As a matter of fact Germany has not yet joined the Union. This is not on account of any unfriendliness or intention to stay out, but is due (so I was told) to a disagreement among several German scientific societies as to the best way to become a member. No doubt this will be settled in the near future. In order to secure a large and representative attendance the President issued a cordial invitation to all astronomers to attend the meeting. The result was that while twenty-three nations are regular members, eight nations which are not members sent delegates amounting to one-eighth of the whole number present. The majority of these came from Germany.

There were present approximately 250 delegates, who were accompanied by members of their families amounting to about 100 persons. Some sixty were from England, forty from the United States, and three from Canada—namely, Dr. J. S. Plaskett of Victoria, Prof. D. Buchanan of Vancouver, and the writer. Leyden has a population of 65,000, compressed into a comparatively small area, and it could not accommodate all the visitors, so a large number were lodged at Noordwijk-aan-Zee, a fine summer resort six miles west on the dunes overlooking the North Sea. Special electric trains were run morning and evening for the convenience of the visitors. These were recognized by two orange flags on the front of the train, while the cars within were supplied with vases containing beautiful cut flowers characteristic of the country.

Official connection with the Union is maintained by the nations in different ways, though always directly through the government or through a national society. Thus, in England the Royal Society is responsible for keeping up adherence to the Union; in the United States, the National Research Council; in Australia, the National Research Council; in Canada, the Federal Government. The annual fees amount to about $86 per five million of population.

Ordinarily, at meetings of scientific societies, papers are read describing researches being carried on by the members, but that procedure is not followed in the Astronomical Union. It has about thirty standing committees, or "commissions", each composed of astronomers specially interested in the subject it deals with. For example, Commission 3 deals with Notations, Units and the Economy of Publications; No. 4 with Ephemerides; No. 12 with Solar Physics; No. 22 with Shooting Stars; and so on. The chairman usually draws up a statement regarding matters in need of consideration and sends it to the members of the committee. Discussion is carried on during the interval between meetings (usually three years), and the views expressed are summarized in a preliminary report which is put in type and made ready for consideration at the meeting. When the members of the committee come together the provisional report is discussed and as passed is sent to the General Assembly of all the delegates for adoption. The discussions in the committee meetings were frequently full of life, and usually there were interpreters to render

into English or French the substance of any remarks which had been made or any resolution which had been offered.

The headquarters for the meeting were in the Stadsgehoorzaal, or Municipal Auditorium. The General Assembly of the delegates met in the Concert Hall, the offices of the General Secretary (Col. F. J. M. Stratton) and the Local Secretary (Dr. C. H. Hins) were in smaller rooms, while the Reception Room, which was in charge of a body of efficient assistants, was in the same building. The various committees met in the rooms of a Girls' School next door.

The reports of the Commissions were usually very technical, referring to details in the astronomer's work, and cannot be given here. Perhaps, however, I might refer to the committee appointed by the International Research Council to further the study of the relationships between solar and terrestrial phenomena, which met with the Solar Physics Commission. Prof. S. Chapman, of the Imperial College of Science, London, gave an outline of the present situation and what is proposed to be done. Since 1925 there has been marked activity in observations bearing on this subject. The work of the Smithsonian Institution on solar radiation has been supplemented by regular observations of ultra-violet radiation at Mt. Wilson and at Tucson in Arizona. Very large variations from day to day have been noted, which will give material for comparing with magnetic and terrestrial phenomena, including those in the earth's atmosphere. Important advances have been made in co-operative schemes of observation of the upper atmosphere, relating to the amount of ozone present, the luminosity of the night sky and the temperature, as inferred from measurements of the transmission of sound over great distances. The latter work appears to confirm the conclusion, previously drawn from meteoric evidence, that at a height of 50 km. or more the temperature of the atmosphere equals or exceeds that of the lowest layer. These temperatures are probably due to the absorption of ultra-violet radiation by the ozone layer in the upper atmosphere. The luminosity of the night sky shows an annual periodicity and strong indications of a slower change in phase with the sun-spot cycle. Studies of the transmission of radio signals have given rise to the belief that their variations are associated with changes

in the ionization of the upper atmosphere. Observations must be continued for some years before positive conclusions can be drawn. A relation between wireless variations and sun-spots has not been definitely established. Laboratory investigations have led to the conclusion that the green auroral line is due to oxygen, but further work is needed to elucidate the nature of the excitation of the molecules or ions which causes the auroral light. It has been recently found that the very high auroral rays, extending up to several hundred kilometres, occur only in situations within the unintercepted beam of sunlight passing outside of the circle dividing the dark and sunlit hemispheres of the earth. A close co-operation of observers in various countries, with special attention concentrated upon some pre-arranged portion of the sun, it is hoped, may provide data which may be correlated to terrestrial phenomena. This is a new attack upon a great problem which undoubtedly will be ultimately successful and with most important results.

The meeting opened on July 5 and lasted until July 13. As there was no hall in Leyden large enough for the purpose, the Inaugural Ceremony took place at the Hague (ten miles away) in the "Ridderzaal", in which the Queen opens parliament. Here the Minister of Education gave an address of welcome, which was followed by short addresses by the President of the Royal Academy of Sciences at Amsterdam, the Rector of Leyden University and the President of the International Astronomical Union. After this there was a reception in the rooms of the restaurant "De Twee Steden" near by. Transportation to and from the Hague was by a special train.

On July 6 in the morning was the first meeting of the General Assembly, with President De Sitter in the chair. The proceedings were conducted in English, but on the platform was a whole battery of vice-presidents and interpreters able to translate from any language which might be used (Plate XVI). The President, in his address, referred to the advantage a small country had in having to learn several languages, and he spoke to the members freely in English, French and German. The various Commissions usually met in the mornings, though sometimes in the afternoons.

On the evening of the 6th there was a reception by the Municipality of Leyden in the Municipal Museum. The Mayor made

an address to the visitors in French, remarking in the course of it that in time past Leyden had been noted for its theologians, but now for its astronomers, and he could not say which brought the people nearer heaven. A graceful reply was made by Professor Schlesinger, of Yale, in English, and the Mayor responded briefly in that language.

On the afternoon of the 7th there was an excursion through various canals to the lake district near Leyden. This afforded a pleasing and interesting view of the surrounding country, including the wonderful Haarlem Lake—or what used to be such. What was once some 72 square miles of water was reclaimed in 1840-1853 and is now a broad level stretch of fertile fields. It is, of course, below the level of the surrounding country and must be kept drained and pumped out.

On Sunday the 8th a visit was made to Haarlem, about 25 miles north. On the way many of the farms were seen from which bulbs go out to supply much of the world. It was interesting to see signs bearing names made familiar through advertisements in American magazines and through catalogues widely distributed. In the Frans Hals Museum at Haarlem are many fine paintings by Frans Hals, who was long a resident here. The city of Haarlem provided, at 2.30 p.m., a recital on the organ of the Cathedral. It is the most celebrated in Holland, and at one time was the finest in the world.

On the afternoon of the 9th there was an exhibition, in the lecture room of the observatory, of interesting old instruments and of Huygens relics, including his first drawing of Saturn's ring, dated 27 September, 1657; and in the evening there was a reception by the Dutch Government at the Hague. On the following day at a special convocation of the University of Leyden honorary degrees were conferred upon H. Deslandres, Director of the Paris Observatory, and F. Küstner, Director of the Bonn Observatory; and this was followed by a reception in the near by Botanic Garden.

A pleasant feature of this reception was the presence of some thirty charming Dutch young ladies, dressed in the peasant costumes of different parts of the country, who acted as waiters (see Plate XX).

On Wednesday, July 11th, there was an all-day excursion to

see the great reclamation works of the Zuyder Zee. By means of a dyke 18½ miles long this body of water is being closed off from the North Sea. In this dyke immense sluice-gates must be placed to allow the escape of the River Yssel to the sea and to permit ships to come in and go out. Other dykes will be built to allow a free course to the river, and then the water of the Zee will be pumped out. The entire work will require thirty years, and the cost will be not less than $36,000,000, not counting the cost of making the reclaimed land ready for cultivation. This is an immense undertaking for a small country with a population of 7 millions, but their past experience in reclamation work has given them courage to go ahead. Some 550,000 acres will be added to the land area of the country—about one-twentieth of the whole. On this excursion a special train carried the 300 visitors to Enkhuyzen, where they embarked on a steamer which took the party to see the great dredges in operation and to inspect the construction of the massive sluice-gates. The population of Holland is about 550 per square mile, and it is estimated that through natural increase the density will be about the same when in thirty years this additional land has been added for cultivation.

On the evening of Friday the 12th a splendid banquet was tendered to the delegates by the Local Committee. About 200 sat down. A continental dinner is conducted somewhat differently from one in America. Here the speeches come after the dinner; there they are interjected during the various courses. They were largely in French, though some replies were in English. Professor Eddington, of Cambridge, England, referred to the invention in Holland of the familiar Leyden jar and remarked that one measures electrical capacity by means of it. He thought the name very appropriate since the people of Leyden were remarkable for their capacity for doing great things.

An extended session of the General Assembly on the 13th brought the meeting to a close. It will be long remembered by those who attended it.

So far I have referred only to meetings for men or men and women together. But a Ladies' Committee arranged several excursions and entertainments for the ladies only. These were to the Hague, Scheveningen, the "Oud-Wassenaar" and other

places. At these the remarkable ability of the Dutch ladies for giving entertainment in foreign languages was made evident.

The next meeting will be in 1932 in the eastern part of the United States early in September. It is proposed to allow the visiting astronomers to observe the total eclipse of the sun on August 31, the path of which crosses Quebec, passing over Sorel, and then crosses Vermont, New Hampshire and Maine; and after the eclipse the meeting will be held at some convenient place.

II. The German Astronomical Society

"Die Internationale Astronomische Gesellschaft", the chief astronomical society of Germany, was founded about sixty years ago and comes together every two years. The 28th meeting was held in Heidelberg on July 18th to 21st, 1928. This date was undoubtedly chosen in the hope that many members of the International Astronomical Union would find their way to Heidelberg. A considerable number did come, and actually representatives of 23 nations were in attendance. Thus the word "Internationale" in the name of the society, which is generally omitted, was justified on this occasion. There were about 170 astronomers present, of whom 18 were from the United States, 12 from Great Britain and 2 from Canada. Indeed there were so many English-speaking people in attendance that the announcements of coming events were made in English as well as in German. I believe this was never done before. The visitors from other countries were received by their German fellow-workers with the greatest cordiality, and the entertainment offered was simply royal in nature.

Heidelberg is an ancient and a beautiful city. It has a population of 72,000, and its chief thoroughfare, about two miles long, runs along the south shore of the River Neckar, which here emerges from its mountainous gorge on its way to the Rhine 12 miles away. If one looks to north or south along the short cross-streets he sees beautiful wooded hills rising abruptly at the end of the streets.

The University of Heidelberg was founded in 1385 and was the chief intellectual stronghold of the Reformation. It is famous for its scientific workers, too. It was here that Kirchhoff and Bunsen made their epochal discovery in spectrum analysis. On a tablet affixed to a large building at 52 Hauptstrasse (now used for

commercial purposes) is an inscription which (translated) says: "In this house Kirchhoff in 1859, along with Bunsen, applied his principle of spectrum analysis to the sun and the stars, and thereby disclosed the chemistry of the Universe". That discovery began a new era in the history of astronomy and led directly to the remarkable advances made since then. On one of the highest peaks overlooking the city is located the University Observatory. Its site is known as the Koenigstuhl (King's seat). It possesses a number of fine instruments and is in charge of Dr. Max Wolf, who is widely known both for his scientific work and his kind and generous nature. To him, his gracious wife, and his son, Dr. W. Wolf, the great success of the meeting is largely due.

The meeting was held in the University Buildings. In the chair was Prof. E. Stroemgren, of Copenhagen, Denmark, who conducted the proceedings in German. These consisted of reports concerning the publications of the Society, the *Jahresbericht*, the Society's finances; and of scientific papers read by the members. Of course, the majority of these contributions were in German though some were in English. Dr. J. Jackson, of the Greenwich Observatory, presented his paper in German. I need not attempt to give a summary of these papers. They were all of a technical nature.

On the afternoon of July 18 the visitors paid a visit to the Observatory. Some ascended the mountain by the cable railway, others by automobile by a longer path; and after an inspection of the instruments and the library Mrs. Wolf entertained the visitors, 200 or more, to a sumptuous supper—not simply an "afternoon tea" as that term is understood in America.

On the evening of the 19th the Government and the University gave the members and their accompanying friends a dinner in the Molkenkur, a fine restaurant picturesquely situated half-way up the mountain-side. As usual, the speeches were delivered while the dinner was in progress. The Minister of Education and the Rector of the University made addresses of welcome to the guests, to which responses were made by Sir Frank Dyson, English Astronomer Royal, and Prof. Frank Schlesinger, of Yale Observatory. Then Prof. J. Mascart, of Lyons, France, speaking in French, offered the toast to "Astronomy". He referred to the international

study of astronomical problems and expressed the earnest desire for unity and good will. He closed with a few words in English and in German. This speech produced a remarkable scene. There was tremendous applause, and amid cries of "Hoch! Hoch!" many guests rushed to shake the hand and clink the glass of M. Mascart. It was a striking demonstration of the feeling of good fellowship of all present.

On July 20 a notable excursion was provided by the city of Stuttgart and a few friends of the Society. Leaving at 8 a.m. by special train we travelled for three hours and came to the village of Weil der Stadt, about 15 miles west of Stuttgart, the capital of Wurtemberg. In this village, in a house which is still standing, the astronomer, John Kepler, was born in 1571. In the market-place, which is surrounded by mediaeval buildings, is a fine monument to Kepler. Here at 11.30 short addresses were delivered by Professors Stroemgren, Wolf and Eddington, and a wreath was placed on the monument. After refreshments in the village hall, during which about 40 school children sang with extraordinary expression and skill, the party boarded the train for Stuttgart. Here the visitors were driven for an hour about the fine city and then to the Villa Berg, the former palace of the King of Wurtemberg. After the war the King withdrew and the City purchased the property. The palace is situated in a splendid park with marvellous gardens and is now used for large receptions and other social functions. The Lord Mayor delivered a short address of welcome to the guests, and on their behalf Dr. R. T. A. Innes, of South Africa, replied (in English). After this all sat down to a sumptuous luncheon provided by the city. At about 6 o'clock the visitors were conveyed back to the city and were given a special demonstration in the Zeiss Planetarium. Of course, I had heard of this wonderful means of illustrating the sky and the motions of the heavenly bodies but had not had the opportunity of seeing it in operation. The representation of the night sky is simply startling. I believe some 15 German cities have Zeiss planetariums, and they are certainly to be complimented. I have seen nothing so realistic and effective for instruction in the motions of the heavens. The return journey began at 9.30, and the entire distance travelled was 175 miles.

Another pleasant feature of the meeting was the assembling together for lunch at the restaurant at the City Hall. These personal contacts with astronomers in different parts of the world, which allow informal discussion of problems together, are perhaps the most valuable features of these gatherings. This meeting at Heidelberg will also remain in the memories of those who were able to be there.

REVIEW OF PUBLICATIONS

Atlas de l'Hémisphère céleste boréal par Fr. Schüller, Prague, 1926.

This atlas was published for the tenth anniversary of the foundation of the Czech Astronomical Society at Prague.

The object of the work is to provide an atlas of the heavens containing not only the fixed stars down to 7.0 visual magnitude, but also a large number of double, variable and coloured stars, as well as of nebulae and star clusters, accessible to instruments of moderate power, in order to permit astronomers, professional and amateur, to make researches of various kinds.

The atlas is divided into two parts of nine plates each. The first part is composed of a plate explanatory of the other eight which represent the equatorial zone of the sky between declinations 30° N. and S. The centres of the plates are on the equator at intervals of 3h. of R.A. The outstanding constellation of Orion serves as the starting-point. The second part also contains eight plates covering the zone from 20° N. to 80° N., and one plate of the region of the north pole.

The fixed stars down to 6.5 visual magnitude are taken from Backhouse's *Catalogue of 9,882 Stars* (1911); those between 6.5 and 7.0 mag., from the Harvard Durchmusterung, *H.A.*, XLV. The atlas contains about three times the number of stars visible to the naked eye.

Great care has been taken to have the areas of the black dots representing the stars proportional to the visual brightness, so that the atlas may be compared directly with a photographic chart.

All the variable stars whose maximum magnitude is 7.5 are included, having been taken from the lists by Miss A. J. Cannon and Müller-Hartwig.

The engraved portion of each plate is 11½ by 13 inches. The names and other designations are in red. The epoch is 1900.

The draughtsmanship of the Atlas is excellent, the printing is first class, and the notation in red is arranged so as to be perfectly clear and yet not to interfere with the recognition of the star images. The Atlas is a great credit to all concerned in its production.

C. A. C.

NEWS AND COMMENTS

The American Astronomical Society will hold its forty-first meeting in New York City, December 26 to 29, in conjunction with the Astronomical Section D of the American Association for the Advancement of Science. A joint meeting of these with the American Physical Society and the American Meteorological Society will be held on December 28. Dr. W. S. Adams, Director of the Mount Wilson Observatory, will give his vice-presidential address on "A Large Telescope and its Possibilities". On January 1, Professor Harlow Shapley, Director of Harvard College Observatory, will speak on "Galaxies of Galaxies".

In *Nature* is announced Professor H. F. Newall's decision to retire from the chair of Astrophysics and from the Directorship of the Solar Observatory at Cambridge University. It is hoped that, freed from administrative duties, he may long continue his scientific work and association with international astronomical committees on which he has been prominent.

M. Pierre Henri Puiseux, member of the Paris Academy of Science, honorary astronomer of the Paris Observatory and honorary professor in the Sorbonne, died on September 28.

It is stated in *Science* that an observatory will soon be under construction at Saltsjoebaden just south of Stockholm. It will have a 36-inch reflector and a 20-inch refractor for photography, and Professor Bertil Lindblad will be the Director.

Mr. A. H. Miller, of the Dominion Observatory, has completed measurements of gravity at Greenwich and Potsdam which will constitute a valuable comparison with the measures at Ottawa and Washington in connection with determinations of the figure of the Earth. Further studies of the application of the torsion balance in measuring local gravity effects will be made through the courtesy of the Geological Survey of Great Britain before Mr. Miller returns to Ottawa.

Notes from the Dominion Astrophysical Observatory, Victoria, contributed by W. E. H.:

"Brigadier-General McNaughton, recently appointed military

commanding officer of this district, visited the observatory with a small party on the evening of June 22.

On June 27 a party of 100 Horticulturists and Plant Pathologists of the Pacific North West, holding their annual meeting in Vancouver, made the 80 mile trip across the strait to see the observatoru. The writer found many of them very interested in the work and appreciative of the half hour's attention given them in the early hours of the evening.

Another very appreciative group was a party of 250 students from the Bellingham Normal School who visited us on July 14. This was a Saturday afternoon trip, but one felt the extra effort to meet their requirements was more than repaid by the expressions of appreciation received. The writer feels that the more courtesies that can be extended to such visitors from across the border the better our international relationships will be.

Another interesting group was that of 20 or more students from the Kwansei Gakuin of Kobe, Japan. This is one of the largest colleges in Japan, and I believe is supported in a large measure by the United Church of Canada. These students were members of their baseball team, which won the national championship and for which they were given a tour of the American continent by a syndicate of newspapers. I think they will have pleasant memories of Victoria to take back with them.

Moving pictures of the equipment here were taken by a C.P.R. publicity man, and also by Edgar B. Van Osdel, Professor of Physics and Astronomy in Redlands University. The latter was lecturing in the summer school conducted by the University of Washington at Seattle and came over to secure the film which he will use in his class room next season.

Mention might be made of many amateurs who have a genuine interest in the subject of astronomy, some of whom are building mirrors of their own, and called for advice on certain matters. A Mr. Holden, whose son is a member of the R.A.S.C., came all the way from Medicine Hat with this particular purpose in view.

In the matter of equipment a new six-inch telescope has been secured from Fecker, and the mounting is now being made locally. It will be used as a finder on the main telescope as with the present ones difficulty is experienced in locating 10^m and 11^m stars on which Dr. Beals is working.

REDeL

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Observation of the Aurora

Dr. E. A. Smith, of Secaucus, New Jersey, reports a brilliant display of the aurora on the night of July 7-8, 1928. It was the most brilliant ever seen in the neighbourhood, being quite comparable to dawn. Streamers and curtains were seen showing the colours, rose-red, green, blue-white and yellow. They appeared very low and in rapid motion and continued from 10.30 p.m. to 1.30 a.m. The maximum was reached in the period 10.40 to 10.57 p.m., a sound being heard.

Mr. A. F. Hunter, of Toronto, under date October 23, 1928, supplies the following notes:

On July 7 and 8 a severe magnetic storm occurred, when there was an extreme range of more than four degrees in the declination fluctuations. A wonderful auroral display was reported by the U.S. Coast Survey at Cheltenham, Maryland. On August 1 there began a four-day period of heavy thunderstorms and sultry weather, such as often takes the place of auroral displays, the electrification of the atmosphere taking another form. There may have been auroral displays in some places. The auroral display during August 26-7 was notable, as the flickering or pulsation of the streamers was very pronounced during the morning hours of both the 26th and the 27th. Again, an auroral display of less magnitude was visible on September 19, and was doubtless strong in higher latitudes. A solar halo of considerable brightness was visible on the 19th. Thus, on four occasions, at intervals of 24 days apart, coinciding with the solar rotation (neglecting the motion of the earth in its orbit), there were marked evidences of solar influence. In higher latitudes auroras are often seen every night, but in the more southerly latitudes these are to be seen only when the magnetic storm is unusually severe.

Audibility of the Aurora

For a number of years the present writer has been collecting evidence regarding the audibility of the aurora and reports of a

considerable number of observations have been printed in the pages of this JOURNAL. Recently there appeared in a newspaper a note on "Musical Auroras" by Garrett P. Serviss, the able American writer on astronomy. He first prints a letter, as follows:

Will you kindly explain the origin of the faintly audible sound that comes with the aurora borealis? This was a little more noticeable during the display last week than of that of this week, neither being as loud as the one several years ago.

The first aurora was much lighter in colour and more fluctuating. The one last week was darker, with more red colour, while the one this week was of a deeper red colour, with less fluctuations. It would seem that the brighter shades give a louder and more musical tone. Or, expressed in radio terms, higher pitch and greater volume.

When I ask any of my friends they think I am "spoofing", but there IS a sound to the aurora, and you may be familiar with it.—X. Pittsburgh, Pa., July 11, 1928.

To this Mr. Serviss makes the reply:

No, I have never heard any sound caused by any aurora I have seen. But other persons have reported hearing sounds which they believed were connected with such displays. They have been described as faint rustling or swishing sounds; but I have never before heard of their having a "musical" tone. Some have denied the possibility of any sound being heard from the play of electric currents at an elevation of many miles above the earth. But the sounds might arise from associated electrical disturbances at the earth's surface, for auroras are always accompanied by more or less derangement of the earth's magnetism, and during a strong aurora the magnetic needle often exhibits extraordinary excitement. I regret that my Pittsburgh correspondent neglected to attach his full address, for his letter indicates that he may be able to contribute interesting facts to our scanty knowledge of the aurora borealis.

I suggest that all who may happen to see an auroral display should endeavour to detect any possible sounds appearing to be caused by it and, if they heard anything of that kind, communicate their observations to the Harvard Observatory. The writer of the letter above also touches on an important subject concerning which amateur observers could probably supply valuable notes, viz., the colours shown by auroras. These are often very striking and the observer should make a sketch in outline on which to note location and relative area of the patches of colour seen. These are often shifting like the streamers and curtains of light themselves. Notes on the changes and the depth of colours, and on the precise character of any sounds heard, would be welcome contributions to science, and I have no doubt that any large observatory would receive them gladly for record, and perhaps in some cases for publication.

There is a very wide and rich field for exploration in nature which professional observers can not fully cover but which now, with the rapid advance of popular education in science, should begin to yield a great store of knowledge

contributed by amateurs, who, by the cultivation of the habit of careful and thoughtful observation, would gain an advantage for themselves perhaps even more valuable than the contributions they would be able to offer to science.

This brought forth a letter from Frank R. Porter, of 228 Main St., Biloxi, Miss., dated September 19, which has been sent to me by the Director of the Harvard Observatory and is given below. I shall be pleased to receive reports of observations at any time:

The aurora borealis does emit sounds—a sort of swishing or hissing sound, followed by a crackling sound like breaking a handful of small dry twigs, the time consumed from the first hissing to the crackling being about two seconds. I observed this phenomenon in Connecticut and the aurora was in small patches of the curtain variety and floated from the north very low down, seemingly not over a hundred feet distant. I heard no musical sounds. This description, I believe, will be verified by a friend who was with me at the time and who is, I think, still living in New Haven, Conn. It took place many years ago, however.

Astronomy in Literature

A reader supplies the following quotation from Samuel Butler's "Erewhon", chapter 19:

The Erewhonians say it was by chance only that the earth and stars and all the heavenly worlds began to roll from east to west and not from west to east, and in like manner they say it is by chance that man is drawn through life with his face to the past instead of to the future.

A Waning Moon on its Back in the West at Daybreak

The place is Tel-el-Amarna, or Akhetaton, on the River Nile. The Libyan mountains are in the west, and the time is the hour before sunrise:

Misty, fluffy stars twinkled like wind-blown flames and a waning copper-yellow moon lay on its back over the black ridge of the Libyan mountains.

—From "Akhnaton, King of Egypt", by Merezhkovsky (1927, page 125).

C. A. C.

The Royal Astronomical Society of Canada

OFFICERS FOR 1928

Honorary President—J. S. PLASKETT, B.A., D.Sc., F.R.S., Victoria, B.C.
President—W. E. HARPER, M.A., Victoria, B.C.
First Vice-President—R. K. YOUNG, Ph.D., Toronto
Second Vice-President—MGR. C. P. CHOQUETTE, M.A., Lic.Scs., Montreal
General Secretary—LACHLAN GILCHRIST, M.A., Ph.D., 198 College St., Toronto
General Treasurer—H. W. BARKER, 198 College St., Toronto
Recorder—E. J. A. Kennedy, Toronto
Librarian—C. A. Chant, M.A., Ph.D., Toronto
Curator—Robert S. Duncan, Toronto
Council—MISS A. VIBERT DOUGLAS, Ph.D., Montreal; ERNEST A. HODGSON, M.A., Ottawa; J. H. HORNING, M.A., Toronto; R. E. DELURY, M.A., Ph.D., Ottawa; R. A. GRAY, B.A., Toronto; COL. W. E. LYMAN, Montreal; REV. DR. D. B. MARSH, Jarvis, Ont.; JOHN SATTERLY, M.A., D.Sc., Toronto; L. A. H. WARREN, M.A., Ph.D., Winnipeg; E. T. WHITE, B.A., D.Paed., London, Ont.; and Past Presidents—JOHN A. PATERSON, M.A., K.C.; SIR FREDERIC STUPART, F.R.S.C.; A. T. DELURY, M.A.; L. B. STEWART, D.T.S.; ALLAN F. MILLER; J. R. COLLINS; W. E. W. JACKSON, M.A.; R. M. STEWART, M.A.; A. F. HUNTER, M.A.; and the Presiding Officer of each Centre as follows—H. M. AMI, D.Sc., Ottawa;
Montreal; MRS. E. L. TAYLOR, Winnipeg; J. A. PEARCE, M.A., Victoria; H. R. KINGSTON, M.A., Ph.D., London, Ont.

TORONTO CENTRE

Board in charge of meetings: J. R. COLLINS (Chairman); DR. J. B. FRASER; R. A. GRAY, B.A.; A. R. HASSARD, B.C.L.; F. T. STANFORD; DR. W. M. WUNDER; E. J. A. KENNEDY (Secretary).

OTTAWA CENTRE

President—H. M. AMI, D.Sc. *Vice-President*—C. C. SMITH, B.A., D.L.S.
Secretary—A. H. HAWKINS, D.L.S., Topographical Surveys, Ottawa
Treasurer—J. F. FREDETTE, D.L.S.
Council—W. W. NICHOL, M.A.; J. S. LANE, B.A.; DR. T. L. TANTON; and Past Presidents—R. M. STEWART, M.A.; J. J. MCARTHUR, D.L.S.; R. E. DELURY, M.A., Ph.D.; R. J. MCDIARMID, M.Sc., Ph.D.; and C. R. COUTLEE, C.E.

MONTREAL CENTRE

Honorary President—MGR. C. P. CHOQUETTE *President*—
First Vice-President—H. E. S. ASBURY
Second Vice-President—JUSTICE E. E. HOWARD
Treasurer—PROF. A. J. KELLY
Secretary—DR. A. V. DOUGLAS, Physics Building, McGill University, Montreal
Council—COL. W. E. LYMAN; A. S. EVE, D.Sc., F.R.S.; J. T. ARMAND; J. LUTRELL; GEO. SAMPLE; MISS J. FLEET; DR. J. B. MCCONNELL; P. A. WATERMAN

LONDON CENTRE

President—H. R. KINGSTON, M.A., Ph.D.
Vice-President—MRS. W. F. BOUGHNER
Secretary-Treasurer—E. T. WHITE, B.A., D.Paed., 34 Marley Place, London, Ont.
Council—REV. R. J. BOWEN, F.R.G.S.; T. C. BENSON; E. H. MCKONE, B.A., D.Paed.; REV. W. G. COLGROVE, M.A.; MISS N. MORRIS

WINNIPEG CENTRE

President—MRS. E. L. TAYLOR
Vice-President—PROF. L. A. H. WARREN
Treasurer—DAVID SAUNDERS
Secretary—MRS. J. NORRIS, 569 Sherburn St.
Council—REV. T. W. MORTON, B.Sc.; C. E. BASTIN; J. H. Kolb; DR. N. J. MCLEAN; A. W. MEGGETT; L. J. REYCRAFT; CECIL ROY and C. F. ELLIS (*Asst. Sec.*).

VICTORIA CENTRE

Honorary President—DANIEL BUCHANAN, M.A., Ph.D.
President—J. A. PEARCE, M.A.
First Vice-President—H. H. PLASKETT, B.A.
Second Vice-President—R. G. MILLER
Secretary-Treasurer—C. S. BEALS, M.A., Ph.D., Dominion Astrophycsial Observatory, Victoria, B.C.
Council—J. P. HIBBEN; J. GOODFELLOW, A. W. GILES; P. S. LANGTON; G. A. BUCKLIN; and Past Presidents—J. S. PLASKETT, D.Sc.; F. N. DENISON; W. S. DREWRY, C.E.; J. E. UMBACH, C.E.; W. E. HARPER, M.A.; JAMES DUFF, M.A.; and P. H. ELLIOTT, M.Sc.